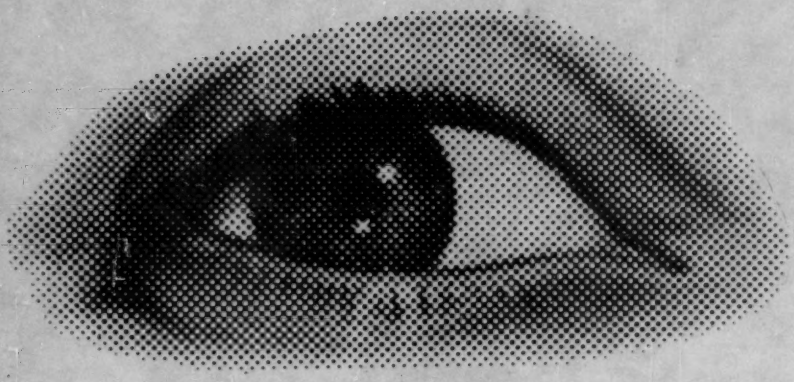
TRANSACTIONS

AMERICAN ACADEMY
of
OPHTHALMOLOGY
and
OTOLARYNGOLOGY

JANUARY - FEBRUARY
1957

Volume 61 Number 1

ANNUAL MEETING, OCTOBER 13-18, 1957, CHICAGO



when the eyes have it

There are five dosage forms of Neo-Synephrine hydrochloride especially formulated for vasoconstriction and mydriasis in ophthalmologic conditions.

CONJUNCTIVITIS
¼% solution.
For rapid relief of congestion, itching, smarting and lacrimation.

REFRACTION, OPHTHALMOSCOPY
2.5% solution.
For prompt and short acting mydriasis virtually free from cycloplegia.

UVEITIS, POSTERIOR SYNECHIAE
10% solution (plain or viscous) or 10% emulsion.
For freeing recently formed posterior synechiae as well as for prevention of synechiae formation in uveitis (with atropine).

GLAUCOMA (certain cases and tests)
10% solution (plain or viscous), 10% emulsion, or 2.5% solution.
For temporary reduction of intra-ocular tension and for the provocative test for angle block.

SURGERY
2.5% solution or 10% solution (plain or viscous).
For short acting powerful mydriatic effect, applied 30 to 60 minutes preoperatively.

Neo-Synephrine®
Hydrochloride

Wide Application in
OPHTHALMOLOGY

Winthrop LABORATORIES
NEW YORK 18, N. Y.

Neo-Synephrine (brand of phenylephrine), trademark reg. U.S. Pat. Off.

TRANSACTIONS

American Academy of Ophthalmology and Otolaryngology

VOLUME 61 JANUARY - FEBRUARY, 1957 NUMBER 1

TABLE OF CONTENTS

PAGE

THE LENS EPITHELIUM IN THE PATHOGENESIS OF CATARACT 7
XIII *Jackson Memorial Lecture*
LUDWIG VON SALLMANN, M.D.

SYMPOSIUM: POSTOPERATIVE CATARACT COMPLICATIONS

I. DELAYED RESTORATION OF THE ANTERIOR CHAMBER; SECONDARY GLAUCOMA; IRIS INCARCERATION AND PROLAPSE; CORNEAL EDEMA 20
JOHN M. MCLEAN, M.D.

II. POSTOPERATIVE IRIDOCYCLITIS; POSTOPERATIVE INFECTION; AFTERCATARACT 33
MICHAEL J. HOGAN, M.D.

III. EPITHELIAL INVASION OF THE ANTERIOR CHAMBER; RETINAL DETACHMENT; CORNEAL EDEMA; ANTERIOR CHAMBER HEMORRHAGES; CHANGES IN THE MACULA 51
A. EDWARD MAUMENEE, M.D.

ON CIGARETTE SMOKING, BRONCHIAL CARCINOMA AND CILIARY ACTION 69
A. C. HILDING, M.D., Ph.D.

SYMPOSIUM: ALLERGY OF THE EAR

THE DIAGNOSIS OF ALLERGY 82
HERBERT J. RINKEL, M.D.

THE EXTERNAL EAR 86
EDLEY H. JONES, M.D.

(Continued on Next Page)

Printed bimonthly, February, April, June, August, October and December, by the Douglas Printing Company, 109 North 18th Street, Omaha 2, Nebraska, for the American Academy of Ophthalmology and Otolaryngology. Editorial and business office, 100 First Avenue Building, Rochester, Minnesota. Subscription price, $10.00 yearly. Second class mail privileges authorized at Omaha, Nebraska.

TABLE OF CONTENTS *(Continued)*

PAGE

THE MIDDLE EAR 91
EUGENE L. DERLACKI, M.D.

THE INNER EAR 97
RAYMOND E. JORDAN, M.D.

DISCUSSION 99
HERBERT J. RINKEL, M.D.

MASS-DISASTER TRACHEOTOME 100
THOMAS C. GALLOWAY, M.D. and JOHN ELSEN, M.D.

EDITORIALS

INDUSTRIAL NOISE AND HEARING LOSS 103

THE PAN-AMERICAN ASSOCIATION OF OPHTHALMOLOGY 104

SECOND CRUISE CONGRESS OF THE PAN-AMERICAN ASSOCIATION OF OPHTHALMOLOGY 105

IN MEMORIAM 106

TONOMETER CALIBRATION: AN ATTEMPT TO REMOVE DISCREPANCIES FOUND IN THE 1954 CALIBRATION SCALE FOR SCHIØTZ TONOMETERS 108
JONAS S. FRIEDENWALD, M.D.†

TONOMETER CALIBRATION: EMPIRICAL VALIDATION 123
PETER C. KRONFELD, M.D.

BOOK REVIEWS 127

NEWS NOTES XXV

POSITIONS AVAILABLE XXVII

CALL FOR PAPERS XXVIII

NEW

True solution
assures
maximum
anti-inflammatory
benefits

STERILE
OPHTHALMIC
SOLUTION

'NEO-HYDELTRASOL'

(PREDNISOLONE 21-PHOSPHATE-NEOMYCIN SULFATE)

Now you can offer your patient needing topical therapy the *unequalled benefits* of the first stable, sterile soluble "predni-steroid" *in true solution.* Sterile Ophthalmic Solution 'NEO-HYDELTRASOL' contains a soluble inorganic ester of the most potent "predni-steroid"—prednisolone 21-phosphate. 'NEO-HYDELTRASOL' provides *these exclusive advantages:*

- **freedom from any particulate matter capable of injuring ocular tissues.**
- **uniform and effective concentrations of prednisolone.**
- **compatibility with ocular tissues and fluids.**
- **stability for long periods (does not need refrigeration).**

Indications: Allergic and inflammatory lesions of the anterior segment; injury due to physical or chemical trauma.

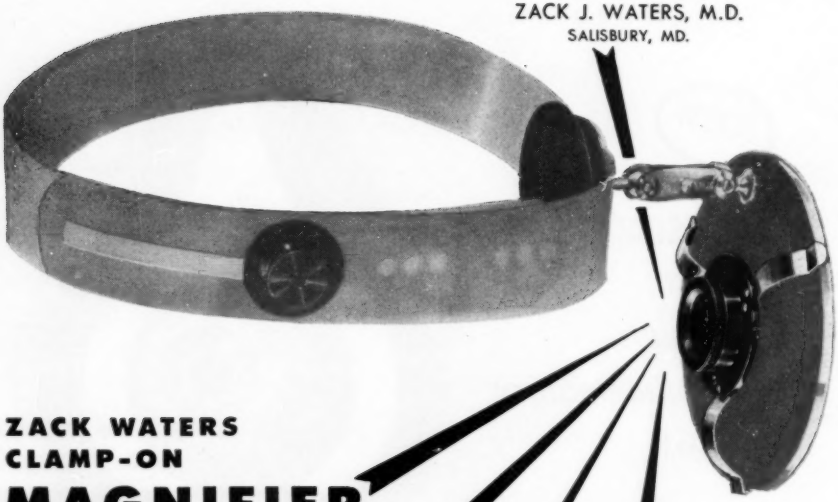
Contraindications: Ocular herpes simplex and ocular tuberculosis.

Supplied: *Sterile Ophthalmic Solution* 'NEO-HYDELTRASOL'—*each cc. contains 5 mg. (1%) prednisolone 21-phosphate (as sodium salt) and 5 mg. Neomycin Sulfate (equivalent to 3.5 mg. neomycin base); 5-cc. vials.*

MSD

MERCK SHARP & DOHME
DIVISION OF MERCK & CO., INC. PHILADELPHIA 1, PA.

DESIGNED BY
ZACK J. WATERS, M.D.
SALISBURY, MD.



ZACK WATERS
CLAMP-ON
MAGNIFIER
FOR HEAD MIRRORS

NEW OPERATIVE EASE

PUT THIS ON YOUR HEAD MIRROR...

- **eliminates glasses for presbyopic**
- **fits the head mirror you now use**
- **clamps on easily, fits snugly**
- **no focusing, no obstruction**
- **sterilizable, sturdy, yet lightweight**

Attach this magnifier to your head mirror (fits any 3½" mirror with convexity of 10"-14" radius curvature)—new operative ease and convenience.

Three lenses of 1, 2 and 3 plus diopter give wide choice of magnification, meet necessary focal distances for examination or surgery of the ear, pharynx, larynx and paranasal sinuses.

E5851 Zack Waters Clamp-on Magnifier with 3 lenses . . . $9.75

ORDER DIRECT

GEORGE P. **Pilling** & SON CO.

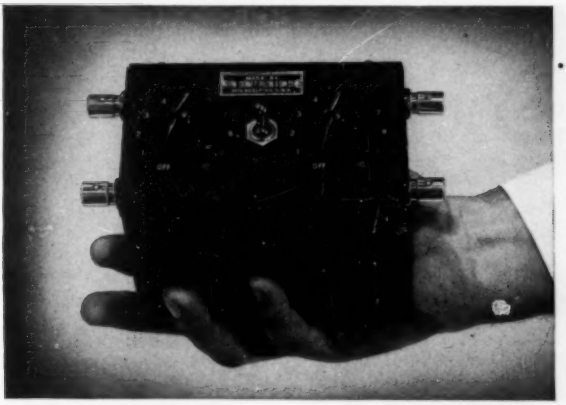
3451 WALNUT STREET • PHILADELPHIA

Pilling New York Office — 4 W. 56th St., N. Y. 19, N. Y., Circle 5-8125
George S. Weigand, 6220 Oakdale Ave., Woodland Hills, Calif.
Charles H. Dunham, 9508 Monroe Ave., Washington 22, D. C.
CABLE ADDRESS: Surgical-Phila.

IRVING WHITE
DOUBLE CIRCUIT BATTERY

Small • Compact • Rheostat Controlled • Two Independent Circuits

for diagnostic lamps



Black Crackle Finish 4"h, 5"w, 3"d. 2¾ pounds

Designed by
Irving White, M.D.
Los Angeles

Cat. No. Br. 1488 $17.50

● Lightweight, easy to carry, for home or office use to light bronchoscopic instruments singly or in pairs.

Spring-type binding posts assure positive contact—red and black signals match Pilling bronchoscopic cords, prevent short circuits. Each pair of posts is controlled by an individual rheostat from "off" to 3 volts current.

This battery contains two Type C industrial dry cells (not flash light batteries); they will give long and reliable service. Replacements may be purchased at most hardware stores or direct from Pilling. Both pairs of posts are powered by one cell, thus if one circuit becomes weak, the second can be engaged by simply turning the switch—there is always one cell in reserve.

The Irving White Battery is available only from Pilling—order direct

GEORGE P. ***PILLING*** & SON CO.

3451 WALNUT STREET
PHILADELPHIA

Pilling New York Office — 4 W. 56th St., N. Y. 19, N. Y., Circle 5-8125
George S. Weigand, 6220 Oakdale Ave., Woodland Hills, Calif.
Charles H. Dunham, 9508 Monroe Ave., Washington 22, D. C.
CABLE ADDRESS: Surgical-Phila.

DISEASES
OF
THE EYE
8th
EDITION
EXCELLENT
and EQUALLY EFFECTIVE
in INFLAMMATION
and/or INFECTION
of the
EXTERNAL EYE
Terra-Cortril®
brand of oxytetracycline and hydrocortisone
OPHTHALMIC SUSPENSION
combines the outstanding therapeutic and prophylactic anti-infective range and effectiveness of TERRAMYCIN® with the proven and predictable anti-inflammatory action of CORTRIL.®
Supplied: In amber bottles of 5 cc., with sterile eye dropper, containing 5 mg. oxytetracycline hydrochloride (TERRAMYCIN) and 15 mg. hydrocortisone (CORTRIL) per cc.
Pfizer
PFIZER LABORATORIES Division, Chas. Pfizer & Co., Inc. Brooklyn 6, New York

Physician and patient satisfaction

has helped make Zenith the world's largest-selling hearing aid

To every physician who has had experience with Zenith Hearing Aids, the reasons for Zenith's leadership in electronic hearing correction are readily apparent:

1. Zenith Quality. More than any other factor, it is the *quality* and *performance* of Zenith Hearing Aids which have won for them such universal acceptance. Precision-built of the finest materials and workmanship, each model reflects Zenith's 37 years of research and experience in radionics exclusively.

2. A Hearing Aid for Every Electronically Correctable Impairment. A total of 816 individual power-tone response modifications are offered by Zenith's current line of seven superb air-conduction instruments, plus an extra-sensitive new bone conductor for those requiring this special help.

3. Ten-Day Money-Back Guarantee. Zenith's ironclad guarantee policy is a positive protection to both patient and physician. No sale is final until a ten-day trial period has proved the instrument satisfactory under actual conditions of use. Your patient must be *completely* satisfied, or his money is refunded.

4. Money-Saving Prices and Operating Costs. No physician likes to feel his patient is going to be overcharged for a hearing aid. Pursuing its famed Crusade to Lower the Cost of Better Hearing, Zenith provides true quality at money-saving prices. An example is the new Zenith "50-X," offering a combination of features not found in other hearing aids, even those selling at $250 and $300. Yet it's priced at only $50 complete. Operates for only about ten cents a week.

5. Diagnosis Left to Physician. Zenith Hearing Aid advertising urges the hard-of-hearing to consult their physician. Dealers are cautioned against following the pseudo-professional "testing" or examination procedures employed by many competitive salesmen. Zenith Hearing Aid Dealers are always instructed to *co-operate* with the medical profession, not to attempt competing with it.

* * *

You are respectfully invited to examine a Zenith Hearing Aid at your convenience on Zenith's 30-Day Free Trial Offer for Physicians. No cost or obligation. Just fill in the coupon below to receive details.

Zenith Hearing Aid Dealers are located in principal cities from coast to coast. Simply consult classified telephone directory for name and address of the one nearest you or mail coupon for list of franchised Zenith Hearing Aid Dealers in your area.

ZENITH®

QUALITY HEARING AIDS

By the Makers of World-Famous Zenith TV, Radios and Amazing "Space Command" TV Tuner

Mail coupon at right to receive a copy of an informative new booklet, "Better Hearing for Your Patient," prepared specifically for physicians.

New free booklet for Physicians!

Zenith Radio Corporation, Hearing Aid Division
5801 Dickens Ave., Dept. 410, Chicago 39, Ill.

Please mail me a copy of "Better Hearing for Your Patient," list of local dealers, and a supply of Zenith literature for my hard-of-hearing patients. Also information on your 30-Day Free Trial Offer for Physicians.

Name .....

Address .....

City ..... **State** .....

"LACRILENS" is a safe lens

The test of time proves that the "LACRILENS"® contact lens can be worn for long periods of time in aphakia and in all sports, including swimming.

Write for Brochure

Manufacturers of all types of Contact Lenses

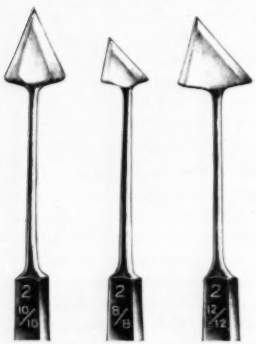
Obrig Laboratories Inc.
49 East 51st Street, New York 22, N. Y.

Obrig®

Branches in PHILADELPHIA • MONTREAL • JOHANNESBURG

Exclusive Distributors — Ernst Grieshaber — Switzerland

Famous Ophthalmic Instruments — Unequaled for perfection!



Grieshaber Suture Needles

5 mm
7 mm
10 mm

#81+#82 Stainless*

Only the Original and Genuine, Grieshaber patterns of eye instruments and cutting edge corneal needles, offer the optimum in precision and guarantee finest operative results!

Finest cutting instruments!

- Keratomes
- Cataract Knives
- Needle Knives
- Trephines
- Delicate Forceps

*Also available in new 4 mm size, for intracorneal suturing.

Order Direct from . . .

Grieshaber Swiss Eye Instruments • 4501 Armitage Avenue CHICAGO 39, ILLINOIS

Shown above: Complete assembly and replaceable components

Sierra®-SHELDEN TRACHEOTOME PAT. APPLIED FOR

DO IT IN SECONDS—
INSERT GUIDE NEEDLE, TROCAR-TUBE: REMOVE NEEDLE — REMOVE TROCAR—THAT'S ALL!

A Must for Surgeons–Anesthesiologists–Hospitals.

R.A. HAWKS DIVISION Sierra Engineering Co.

WRITE FOR FREE CATALOG

Before using, see complete technic packed with Tracheotome

Available through Surgical Supply Dealers

123 E. MONTECITO AVE., SIERRA MADRE, CALIF.

Prescribe the ONE bifocal for NATURAL VISION

there's really only ONE!

If the wearer of the glasses you prescribe knew what you know about bifocal lenses—performance, quality and price—don't you think he'd choose the best for himself? There's *one* multifocal lens of quality and scientific merit that earns for it the simple designation "best." That is the Orthogon Panoptik.

ORTHOGON PANOPTIK

Wide at the top

Round corners

No wasted lens areas

BAUSCH & LOMB

SINCE B&L 1853

Available in white, soothing luxurious Soft-Lite, and cool comfortable Ray-Ban

A COMPLETE TREATMENT ROOM IN A SMALL AREA

The dimensions in the above photograph are 5' 9" along one wall and 4' 2" along the other. In this area, conveniently arranged, is everything needed to make a complete examination. However, it need not be confined to this limited space. The complete absence of piping and wiring is especially noticeable. A number of other arrangements will be furnished on request.

Treatment Stand: Covered with stainless steel. Contains: air regulator with gauge, tubing, cutoff and air filter; nasopharyngoscope rheostat; push button; cautery transformer and rheostat; transilluminator complete with rheostat, cord, handle, lamps, antrum and frontal tips; seven metal drawers on fiber runners and one large drawer for towels; waste container; bakelite covered work table; space for six spray bottles, twelve solution bottles, shelf for cotton jars; pocket for history card or prescription blanks; and a spray bottle heater; the whole presents an attractive appearance and will not tarnish and is easy to keep clean. Price complete without glassware $195.00. Without air but with electrical equipment $165.00. With air equipment only $150.00. Without either air or electrical equipment $115.00. Glassware available.

Chair: Can be placed in horizontal position, will not tip in this position; raised and lowered by large hand wheel; paper covered headrest removable; locked with foot-pedal; bakelite armrests removable. Back locks rigidly in any position. As shown in brown or green. $150.00.

Turning Chair: By adding a footrest and the necessary handles this chair can be used for turning tests. All the additional equipment is easily and quickly removable. Add. $30.00.

Combined Suction and Cuspidor: This is an entirely new piece of equipment. It was designed to eliminate the cost of installing a separate suction. The apparatus is 12" wide and projects 13¼" from the wall. The flushing rim and the suction is furnished with a vacuum breaker and should meet all plumbing requirements. Stop and trap not furnished. Available in ivory, green and white. Price $95.00.

Ceiling Light: A telescopic light attached to the ceiling. May also be attached to base board in back of chair. Available in 4, 5, 6 and 7 ft. (extended). 4 ft. $16.50 (add one dollar per ft.).

Light Shield: Takes an ordinary 100 watt lamp. Will not burst; spot can easily be rotated. $5.00.

Stool: A soft upholstered stool with easy running ball bearing stem casters. $20.00. Stool with back, $26.00.

All the equipment shown in this advertisement, ready to be attached to your air system, $531.50.

CATALOG SENT ON REQUEST

All Prices are F.O.B. Los Angeles, Calif.

Surgical — Mechanical — Research, Inc.

1901-1903-1905 Beverly Blvd. SMR Los Angeles 57, Calif.

OPHTHALMOS

Almocarpine*

THE OPHTHALMOS BRAND OF PILOCARPINE HCl. SOLUTIONS

THE MOST EFFECTIVE TREATMENT FOR THE GLAUCOMAS

POTENCY . . .

Almocarpine solutions have no wetting or thickening agents that may affect the activity and potency of the drug.

PURITY . . .

The Almocarpine formula, designed to prevent drug degradation, has been perfected so as to virtually eliminate patient intolerance and secondary drug irritations.

PERMANENCE . . .

Almocarpine is packaged in autoclaved containers which do not affect the contents. They carry no expiration dates.

Ophthalmos Almocarpine is preferred in most hospitals where ophthalmic surgery is performed

Almocarpine produces immediate, maximum and lasting miosis. It reduces intraocular pressure with no irritation of the ocular tissue or ciliary spasm. It causes no change in refractive error.

OPHTHALMOS

THE PINNACLE OF PROFESSIONAL EXCELLENCE

OPHTHALMOS, Inc.

Union City, New Jersey

*Almocarpine is a trademark of Ophthalmos Inc. It is available in ½%; 1%; 2% and 4% strengths in 15 cc. dropper bottles.

minimize the
time factor
in refraction
30 minutes after instillation of cyclogyl . . .
3-6 hours* after instillation of cyclogyl . . .

with

cyclogyl® *hydrochloride*

brand of cyclopentolate hydrochloride

Rapid onset of action,[1,2] brief duration,[1,2] and consistent depth of cycloplegia make Cyclogyl ". . . the drug of choice for routine refraction."[1]

Cyclogyl does not produce local or systemic toxic effects, and is relatively nonirritating and nonsensitizing;[3,4] *it has not been reported to cause a significant variation in intraocular tension.*[4,5] Cyclogyl is effective in highly pigmented eyes, and may be used for persons of all ages.[4] No pretreatment is required.

Just one or two drops provides complete cycloplegia, thereby conferring a saving in medication cost.

Send for literature and samples

Indications: Refraction; as a mydriatic in controlling iritis, iridocyclitis, keratitis, and choroiditis; to prevent lenticular adhesions; with miotics for preventing or breaking adhesions in infection; preoperatively, for cataract or other appropriate eye surgery.

Supplied: 0.5% Solution in 15 cc. dropper bottles; 1% Solution in 2 cc. and 15 cc. dropper bottles.

*When a miotic is used. Otherwise, in less than 20 hours.

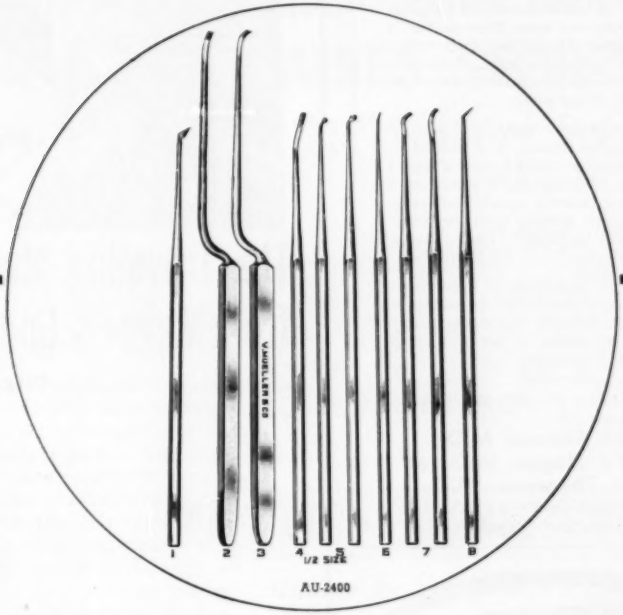
1. Rasgorshek, R. H. and McIntire, W. C.: Am. J. Ophth. 40:34 (July) 1955. • 2. Ehrlich, L. H.: N. Y. State J. Med. 53:3015 (Dec. 15) 1953. • 3. Gettes, B. C.: A.M.A. Arch. Ophth. 51:467 (April) 1954. 4. Council on Pharmacy and Chemistry: J.A.M.A. 158:1523 (Aug. 27) 1955. • 5. Stolzer, I. H.: Am. J. Ophth. 36:110 (Jan.) 1953.

Schieffelin & Co. / Since 1794

PHARMACEUTICAL AND RESEARCH LABORATORIES

28 Cooper Square, New York 3, N. Y.

In Canada:
W. Sofin Ltd., Montreal 25, Quebec



New Rosen Instrument Set

For Stapes Mobilization

V. Mueller Catalog Number—AU-2400. 10 instruments in khaki roll.
Price—$44.00

1. Incision knife. For incision through skin over bony canal wall, about 6-7 mm. external to drum.
2. Bayonet Separator. (Lesser curve.)
3. Bayonet Separator. (Full curve.) Skin is separated from bone as far as drum, from beginning of incision.
4. Separator. (Slightly angled.) Drum is finally lifted out of sulcus, reflected upward upon itself like apron.
5. Separators. (Left, small; Right, large.) 2-3 mm. of very edge of incus is removed, making all necessary elements visible.
6. Probe. Finely pointed, for testing mobility of footplate of stapes.
7. Mobilizers. (Left, full curved, narrow; Right, lesser curved, narrow.) For applying variable pressure downward against neck of stapes.
8. Explorer. For use when necessary to sever adhesions involving ossicles.

Armamentarium

V. MUELLER & CO.
330 South Honore Street
Chicago 12, Illinois
DALLAS • HOUSTON • LOS ANGELES • ROCHESTER, MINN.

URGENT REQUEST

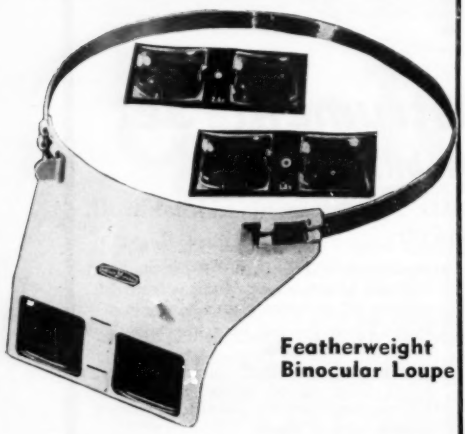
The Uveitis Laboratory, University of California School of Medicine, San Francisco, is interested to obtain freshly enucleated eyes from patients with **all types of uveitis** and other endogenous inflammations. Attempts are being made to isolate etiologic agents from these eyes.

The eyes should **not** be fixed in preservatives or frozen, but placed in a sterile bottle, packaged, and shipped as quickly as possible. Please send specimens air express, special delivery, **collect.** Enclose history and findings, and mark the package "Fresh Tissue Specimen—Rush."

A report of isolations of organisms and pathologic findings, including a slide, will be sent to the contributor. Credit will be given in any resulting publications, if desired.

Telegraph collect if specimen is being sent. Send eyes to . . .

Samuel Kimura, M.D.,
Michael J. Hogan, M.D., or
Phillips Thygeson, M.D.
University of California School of Medicine, San Francisco 22



Featherweight Binocular Loupe

Permits interchange of higher or lower power lens mountings. Designed to give complete comfort when wearing glasses. Can be sterilized without harm. Now available with choice of 1½X, 2X or 2½X. **$12.50** P.P. Additional powers **$5** pr. ppd.

BARNETT Optical Laboratories
3120 North Cicero Ave., CHICAGO 41, ILL.

The Traveling Man from Mager & Gougelman

Eddie Kerr has helped physicians fit thousands of patients with artificial eyes. Like the other experts from our offices, he provides you with technical information and assistance on difficult cases. The samples in his case will match many patients. Or, he can make eyes that perfectly match with the materials he carries. One of our experienced men visits most areas regularly—another reason to call or write our nearest office for your next ocular prosthesis.

Complete Artificial Eye Service

- Eyes custom made—glass or plastic
- Eyes from stock sent on same day order received—glass or plastic
- Damaged or broken eyes accurately matched
- Fitted to all types of motility implants
- Implants, X-Ray therapy shields, foreign body locators
- Superior Quality—Finest Workmanship

Mager and Gougelman inc.

Serving the Profession Since 1851

30 N. Michigan Ave. Chicago 2, Illinois
120 E. 56th St. New York 22, N. Y.

CLEVELAND DETROIT HOUSTON (Soper Bros.)
KANSAS CITY MINNEAPOLIS ST. LOUIS
BOSTON PHILADELPHIA PITTSBURGH WASHINGTON

... In Ophthalmic Medication

A PRECEDENT-SETTING INNOVATION

...the 1 cc DROP-TAINER® STERI-UNIT*

Single Dose Disposable Unit with Sterile Outer Surfaces

STERILE • READY FOR USE

The Ultimate In Safety and Convenience

*Trade Mark

Patent Pending

Sterile Aqueous Solutions pH and tonicity adjusted

Atropine Sulfate 1%

Atropine Sulfate 0.5 %

Eserine Salicylate 0.5%

Fluorescein Sod. 2%

Homatropine HBr 5%

Pilocarpine HCl 2%

Sulfacetamide Sod. 15%

Tetracaine HCl 0.5 %

plus

Sterile Saline (15cc)

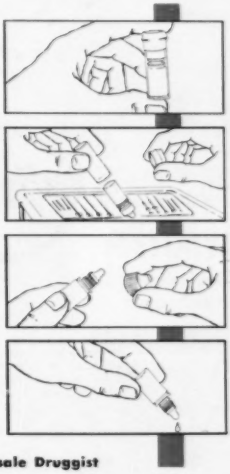
In Boxes of Ten Economically Priced

1 Drop-Tainer® Steri-Units* may be stored under ordinary conditions and handled freely prior to opening the outer vial without danger of contaminating the sterile surface of the enclosed Drop-Tainer®.

2 The cellulose band and vial closure are removed together by pulling with a slight twist. Care should be exercised so that the fingers do not brush across the open mouth of the vial. The Drop-Tainer® may then be allowed to fall upon the sterile instrument tray by inverting the vial.

3 The entire outer surface of the Drop-Tainer®, as well as its content, is sterile and thus may be safely handled by the surgeon. The cap of the Drop-Tainer® is quickly and easily unscrewed—and the specially designed dropper tip needs no puncturing before use.

4 Gentle pressure on the sides of the Drop-Tainer® will empty its contents in uniform drops; or, rapid squeezing will produce a stream which is sometimes desirable.



Now Available From Your Service Wholesale Druggist

For Further Information, Write:

© 1957

Alcon laboratories, inc. • p. o. box 1959 • fort worth, texas

DT SU—1

THE NEW YORK POLYCLINIC
MEDICAL SCHOOL AND HOSPITAL
(ORGANIZED 1881)

(The Pioneer Post-Graduate Medical Institution in America)

EYE, EAR, NOSE AND THROAT

A three months' combined full-time refresher course consisting of attendance at clinics, witnessing operations, lectures, demonstration of cases and cadaver demonstrations; operative eye, ear, nose and throat on the cadaver; clinical and cadaver demonstrations in bronchoscopy, laryngeal surgery and surgery for facial palsy; refraction; radiology; pathology, bacteriology and embryology; physiology; neuro-anatomy; anesthesiology; physical medicine; allergy, as applied to clinical practice. Examination of patients preoperatively and follow-up postoperatively in the wards and clinics. Attendance at departmental and general conferences.

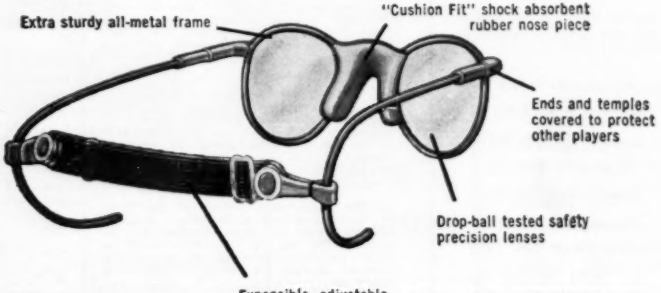
For information about this and other courses address
THE DEAN: 345 West 50th St., NEW YORK 19, N. Y.

This fall and winter... prescribe Benson's

*ALL AMERICAN** ATHLETIC GLASSES

Designed for rough treatment

Your athlete patients will receive maximum comfort and protection during competition if they wear *ALL AMERICAN** ATHLETIC GLASSES... practical and useable on all noses for almost every sport.


Extra sturdy all-metal frame
"Cushion Fit" shock absorbent rubber nose piece
Ends and temples covered to protect other players
Drop-ball tested safety precision lenses
Expansible, adjustable "Glass-Gard"* headband

Prices on request.
A complete sample may be ordered at nominal cost from your supplier or
BENSON OPTICAL COMPANY.

For your protection and ours, look for the trademark AA on the lenses of every pair of *ALL AMERICAN** ATHLETIC GLASSES.

*Copyright

Since 1913 — Benson OPTICAL COMPANY — *Executive Offices • Minneapolis 2, Minn.*

COMPLETE LABORATORIES CONVENIENTLY LOCATED IN UPPER MIDWEST CITIES

widest
approach
to
eye disorders
combines prednisolone and sulfacetamide
antibacterial
antiallergic
anti-inflammatory
also available as METIMYD Ointment with Neomycin
METIMYD,® brand of prednisolone acetate and sulfacetamide sodium.
®T.M.
MV-J-2-454
Schering
METIMYD
Ophthalmic
Suspension

perfect
fusion
for
sharp
focus
in
eye disorders

- infection
- inflammation
- injury
- allergy

Sodium SULAMYD,® brand of Sulfacetamide Sodium U.S.P.
METIMYD,* brand of prednisolone acetate and sulfacetamide sodium.
CORTICLORON,® brand of cortisone acetate and chlorprophenpyridamine preparations.

*T.M.

MM-J-1-456

storz Surgical Instruments

NEW - LIGHT - POWERFUL

Storz Atlas **Handy Eye Magnet**

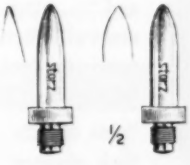
E-6650—Eye Magnet, Atlas: complete with four tips in wooden case and separate rectifier with footswitch. Small size for maneuverability and ease of handling. The magnet weighs 4.6 lbs. The rectifier with footswitch weighs 8.7 lbs. The type of tip selected is dependent on the position of the splinter. For strongest pulling power, the large cone tip is applied. More effective results are obtained by stepping on the footswitch repeatedly to get short interrupted pull rather than a long steady pull.

Power: The absolute pulling power at the flange is 12.5 kg. or 28 lb. The ball jump power is 38.5 mm. The handling is not interfered with by strong directional pulls.

Advantages... **Small size—Light weight—POWER! —**

Made for 110 volt, 60 cycle, alternating current. If other current or voltage is desired, please specify. Uses 150 watts. Developed and tested at the University Eye Clinic in Kiel.

Complete—$149.50



E-6655 Magnet Tip, BONACCOLTO: intra-ocular, large..... **$3.75**

E-6654 Magnet Tip, BONACCOLTO: intra-ocular, small..... **$3.75**

These tips are not included with magnet. Please order separately.

Storz Instruments are available from Storz salesmen only. We do not distribute under any other name or trademark.

Order directly from

Storz Instrument Company

4570 Audubon Ave. **St. Louis 10, Mo.**

Sigmamycin*

OLEANDOMYCIN TETRACYCLINE

added certainty in treatment of respiratory infections

new multi-spectrum synergistically strengthened antibiotic formulation

SIGMAMYCIN adds certainty in antibiotic therapy, particularly for the 90% of patients treated at home or in the office where sensitivity testing may not be practical, and provides: a new maximum in therapeutic effectiveness, a new maximum in protection against resistance, a new maximum in safety and toleration.

Supply: Capsules, 250 mg. (oleandomycin 83 mg., tetracycline 167 mg.). Bottles of 16 and 100.

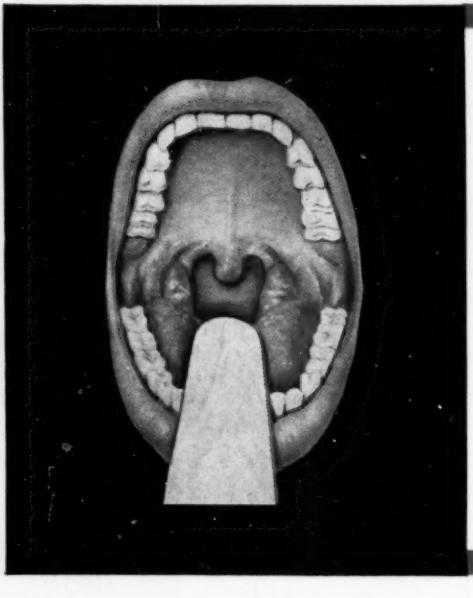
. . . and for a new maximum in palatability

New mint-flavored Sigmamycin for Oral Suspension, 1.5 Gm. in 2 oz. bottle; each 5 cc. teaspoonful contains 125 mg. (oleandomycin 42 mg., tetracycline 83 mg.).

*Trademark

Pfizer

PFIZER LABORATORIES, *Division, Chas. Pfizer & Co., Inc.*, Brooklyn 6, N. Y.
World leader in antibiotic development and production



"...effective...in the treatment of a variety of infections seen regularly by the practicing clinician..." including pharyngitis, bronchitis and other respiratory infections

and "... often useful in the treatment of infections due to staphylococci resistant to one or several of the regularly used antibiotics"

"side effects . . . [are] notable by their absence"[1]

1. Carter, C. H., and Maley, M. C.: Antibiotics Annual 1956-1957, New York, Medical Encyclopedia, Inc., 1957, p. 51.

A Single Source
for Your
ARTIFICIAL EYE
and
ORBITAL IMPLANT
needs

All Plastic, Artificial Eyes

Stock Eyes
Stock Modifications
Custom Eyes
Cosmetic Cover Lenses
Duplications of Glass or Plastic Eyes

Orbital Implants

AO Buried Mesh (Lemoine)
Hollow Buried (Bonaccolto)
Hollow Cone (Berens)
Evisceration (Berens)
Lucite & Polyethylene Spheres
Postoperative Conformers

Information on this program and operative procedures may be obtained by writing to the Monoplex Department, American Optical Co., Southbridge, Massachusetts.

American Optical
COMPANY

See You at the Fair...

11
TEN

MILLION, THANKS...

YES, the *total* has changed . . . Browline® frames have passed the eleven million mark, thanks to their still increasing preference.

The *reasons* for preferring Browlines have not changed—their advantages in patient approval of their styling and comfort . . . ease in fitting . . . interchangeability . . . readily available styles, colors and sizes—in depth . . . dependable quality . . . plus the fact they're 'SHURON.'

In your choice of lenses, cases, and machinery, too, "the swing is to Shuron." Your 1955 orders exceeded those of 1954 by more than 20% . . . and are even higher this year.

We appreciate your preference . . . a preference that makes Shuron the world's largest organization devoted exclusively to serving the ophthalmic profession.

SHURON OPTICAL COMPANY, INC. SHURON® **Geneva, N.Y. Rochester, N.Y.**

JUST AS A REMINDER

4 E.N.T. products to remember!

AURALGAN®
EAR DROPS

IN ACUTE OTITIS MEDIA
SAFE AURALGESIC
AND DECONGESTANT

O-TOS-MO-SAN®
BACTERICIDAL – FUNGICIDAL

BROAD-SPECTRUM
THERAPY WITHOUT
ANTIBIOTICS

RHINALGAN®
NASAL SPRAY

SAFE!
"NOT JUST ANOTHER
DECONGESTANT"

LARYLGAN®
THROAT SPRAY • GARGLE • SWAB

FOR INFECTIOUS
AND NON-INFECTIOUS
THROAT INVOLVEMENTS

DOHO CHEMICAL CORP., 100 VARICK ST., NEW YORK 13, N.Y.

EASIEST WAY TO TREAT A PATIENT

AO Deluxe Chair

Finally! For the professional office...the color, beauty and sleek styling of modern good design. The AO Deluxe Chair . . . easy-to-use, easy-to-care-for, easy-to-look-at, and above all, more comfortable for your patient.

The new footrest and support, the newly styled arms, combine great strength with beauty. The new backrest is wider, comfortable — its shape tastefully blends with the footrest support. Cushions are thick foam rubber, contour curved to position your patients properly.

Warm, friendly, light-hearted colors replace yesterday's more somber tones. A warm ivory tan, crisp jade green and newest of all — a lovely shade of coral. This beauty will last too. Amazing semi-gloss Epoxy baked enamel on base, arm and unit is harder, chip and abrasion resistant. Smart Bark-Weave Naugahyde upholstery washes clean in seconds.

Full range of adjustments, choice of completely enclosed motor-operated base or more economical foot operated model.

Visit your nearby Sales Representative or write —

American Optical Company

INSTRUMENT DIVISION, BUFFALO 15, NEW YORK

MANUALS

	Price
RETINAL DETACHMENT, H. Arruga, et al.	$1.00
OCULAR SURGERY, Conrad Berens and Michel Loutfallah	1.00
CATARACT TYPES, F. C. Cordes	1.00
SLIT LAMP BIOMICROSCOPY, E. Goar, et al.	1.00
OUTLINE OF NEURO-OPHTHALMOLOGY, P. J. Leinfelder	1.00
DESCRIPTION OF THE ORBIT, McCotter, Fralick and Henderson	1.00
GLAUCOMA, Samuel J. Meyer	1.00
THE INTERPRETATION OF VISUAL FIELDS, C. W. Rucker	1.00
DISTURBANCES OF OCULAR MOTILITY, Richard G. Scobee	1.00
REFRACTION, Daniel Snydacker and Frank W. Newell	1.00
EXTRINSIC EYE MUSCLES, H. Saul Sugar	1.00
PRINCIPLES OF OTOLARYNGOLOGIC PLASTIC SURGERY, Oscar J. Becker	1.00
RADIOGRAPHIC ANATOMY OF THE TEMPORAL BONE, J. Brown Farrior	1.00
EXAMINATION OF THE LABYRINTH IN RELATION TO ITS PHYSIOLOGY AND NONSUPPURATIVE DISEASES, W. J. McNally and E. A. Stuart	1.00
NONSURGICAL COMPLICATIONS OF OTOLARYNGOLOGIC SURGERY, J. J. Pressman, et al.	1.00

MONOGRAPHS

HELPFUL HINTS FOR HANDLING THE HEARING HANDICAPPED, Gordon D. Hoople et al	$0.25
HEARING TESTS, Arthur L. Juers	0.25
PHYSIOLOGY OF THE LARYNX, J. J. Pressman and George Kelemen	.50
THE EMBRYOLOGY OF THE EAR, NOSE, AND THROAT, O. E. Van Alyea	0.25
STRABISMUS: A SYMPOSIUM, Kenneth C. Swan et al.	0.50
REFRACTION DIFFICULTIES Clarence A. Veasey, Jr.	0.50

ABSTRACTS

Set contains outlines, briefs of instruction courses as presented at Academy meetings. Unbound.

Ophthalmology:	1954	$3.50
	1955	5.00
	1956	7.50
Otolaryngology:	1954	2.00
	1955	2.00
	1956	2.50

TRANSACTIONS

Subscription:	Per year, bimonthly publication	$10.00
Single issue:	Through 1950	0.50
	1951 through 1956	1.00
	1957	2.00

BOUND VOLUMES

Transactions: Records of meetings held 1917 through 1949	Ea.	$1.50
Vol. 55 (1951) through Vol. 59	Ea.	5.00
Tonometry—Tonography, Decennial Report (Bound)	Ea.	3.00

FILMS — LANTERN SLIDES — FILM STRIPS

THE EMBRYOLOGY OF THE EYE, a motion picture in color with sound. Available on one reel or in two parts on two reels with metal containers and mailing case — Per Print	$250.00
176 Lantern Slides from above film, 2 × 2, in color Mounted in glass, with wooden filing box	125.00
Mounted in cardboard, with plastic and plywood filing box	75.00
Film Strips, from above film, 32 mm. Set of six (176 frames), in color, in metal containers	25.00
THE EMBRYOLOGY OF THE EAR, a motion picture in color with sound. On three reels with metal containers and mailing case — Per Print	500.00

SEND ORDER WITH REMITTANCE TO

W. L. BENEDICT, M.D., 100 FIRST AVENUE BUILDING, ROCHESTER, MINNESOTA

TRANSACTIONS

AMERICAN ACADEMY
of
OPHTHALMOLOGY
and
OTOLARYNGOLOGY

VOLUME 61
1957

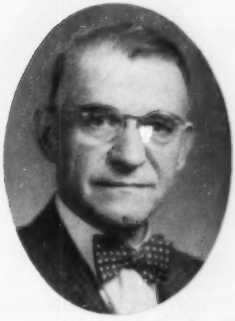
LETTERPRESS IN U.S.A.

OFFICERS *for* 1957

President
ERLING W. HANSEN

President-Elect
LEROY A. SCHALL

Executive Secretary-Treasurer
WILLIAM L. BENEDICT



First Vice-President
LOUIS H. CLERF

Second Vice-President
DAVID O. HARRINGTON

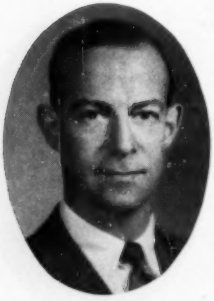
Third Vice-President
O. E. VAN ALYEA

Secretary for Ophthalmology
KENNETH L. ROPER

Secretary for Otolaryngology
EUGENE L. DERLACKI

Secretary for Instruction
Ophthalmology
A. D. RUEDEMANN

Secretary for Instruction
Otolaryngology
and Maxillofacial Surgery
DEAN M. LIERLE



Secretary for Home Study Courses
DANIEL SNYDACKER

Secretary for Public Relations
GLEN GIBSON

American Academy of Ophthalmology and Otolaryngology

THE COUNCIL — 1957

Erling W. Hansen, Minneapolis ..... President
LeRoy A. Schall, Boston ..... President-Elect
Louis H. Clerf, St. Petersburg, Florida ..... First Vice-President
David O. Harrington, San Francisco ..... Second Vice-President
O. E. Van Alyea, Chicago ..... Third Vice-President
Walter H. Theobald, Chicago ..... Past President
Algernon B. Reese, New York ..... Past President
A. C. Furstenberg, Ann Arbor, Michigan ..... Past President
William L. Benedict, Rochester, Minn. ..... Executive Secretary-Treasurer; Editor and Business Manager of the TRANSACTIONS
Kenneth L. Roper, Chicago ..... Secretary for Ophthalmology
Eugene L. Derlacki, Chicago ..... Secretary for Otolaryngology
A. D. Ruedemann, Detroit ..... Secretary for Instruction in Ophthalmology
Dean M. Lierle, Iowa City ..... Secretary for Instruction in Otolaryngology and Maxillofacial Surgery
Daniel Snydacker, Chicago ..... Secretary for Home Study Courses
Glen Gibson, Philadelphia ..... Secretary for Public Relations
Sam E. Roberts, Kansas City, Missouri ..... Councillor
Harold H. Joy, Syracuse, New York ..... Councillor
William J. McNally, Montreal, Que., Canada ..... Councillor
Victor A. Byrnes, Washington, D. C. ..... Councillor

COUNCIL COMMITTEES

EXECUTIVE, RESEARCH AND FINANCE

Erling W. Hansen, *Chairman*
Walter H. Theobald — LeRoy A. Schall
Algernon B. Reese — Sam E. Roberts
A. C. Furstenberg — William L. Benedict

RESEARCH AND FINANCE
(Subcommittee of Executive, Research and Finance)

Walter H. Theobald, *Chairman*
Erling W. Hansen — William L. Benedict

ACTIVITIES

Sam E. Roberts, *Chairman*
Harold H. Joy — LeRoy A. Schall
William J. McNally — Louis H. Clerf
Victor A. Byrnes

JUDICIAL

Erling W. Hansen, *Chairman*
Sam E. Roberts — William J. McNally
Harold H. Joy — Victor A. Byrnes

BOARD OF COUNCILLORS

Sam E. Roberts, *Chairman*
Harold H. Joy — Victor A. Byrnes
William J. McNally

BOARD OF SECRETARIES

William L. Benedict, *Chairman*
Kenneth L. Roper — Dean M. Lierle
Eugene L. Derlacki — Daniel Snydacker
A. D. Ruedemann — Glen Gibson

PROGRAM

Erling W. Hansen, *Chairman*
LeRoy A. Schall — Eugene L. Derlacki
Louis H. Clerf — A. D. Ruedemann
Sam E. Roberts — Dean M. Lierle
William L. Benedict — Daniel Snydacker
Kenneth L. Roper — Glen Gibson

STANDING COMMITTEES

CONSERVATION OF HEARING
Executive Committee

Dean M. Lierle, M.D., *Chairman*, Iowa City, Iowa
Lawrence R. Boies, M.D. ..... Minneapolis, Minn.
John E. Bordley, M.D. ..... Baltimore, Md.
Norton Canfield, M.D. ..... New Haven, Conn.
Hallowell Davis, M.D. ..... St. Louis, Mo.
Kenneth M. Day, M.D. ..... Pittsburgh, Pa.
Edmund P. Fowler, Jr., M.D. ..... New York, N. Y.
Meyer S. Fox, M.D. ..... Milwaukee, Wis.
Aram Glorig, Jr., M.D. ..... Los Angeles, Calif.
Victor Goodhill, M.D. ..... Los Angeles, Calif.
Stacy Guild, Ph.D. ..... Baltimore, Md.
Gordon D. Hoople, M.D. ..... Syracuse, N. Y.
Howard P. House, M.D. ..... Los Angeles, Calif.
Raymond E. Jordan, M.D. ..... Pittsburgh, Pa.
Arthur L. Juers, M.D. ..... Louisville, Ky.
Charles E. Kinney, M.D. ..... Cleveland, Ohio
John R. Lindsay, M.D. ..... Chicago, Ill.
H. E. McHugh, M.D. ..... Montreal, Que., Canada
James W. McLaurin, M.D. ..... Baton Rouge, La.
W. J. McNally, M.D. ..... Montreal, Que., Canada
C. Stewart Nash, M.D. ..... Rochester, N. Y.
Harold Schuknecht, M.D. ..... Detroit, Mich.
George E. Shambaugh, Jr., M.D. ..... Chicago, Ill.
K. M. Simonton, M.D. ..... Rochester, Minn.
J. Tonndorf, M.D. ..... Iowa City, Iowa
Henry L. Williams, M.D. ..... Rochester, Minn.

Consultants

Raymond Carhart, Ph.D. ..... Evanston, Ill.
Eva Thompson Carson ..... Glenview, Ill.
Howard A. Carter ..... Chicago, Ill.
Merle Lawrence, Ph.D. ..... Ann Arbor, Mich.
Scott N. Reger, Ph.D. ..... Iowa City, Iowa
Walter A. Rosenblith, Ph.D. ..... Cambridge, Mass.

COMMITTEE ON IMPLANTS AND IMPLANT TECHNIQUES

A. D. Ruedemann, M.D., *Chairman*, Detroit, Mich.
James H. Allen, M.D. ..... New Orleans, La.
Peter H. Ballen, M.D. ..... Hempstead, L. I., N. Y.
Alson E. Braley, M.D. ..... Iowa City, Iowa
J. Gordon Cole, M.D. ..... New York, N. Y.
Norman L. Cutler, M.D. ..... Wilmington, Del.
Orwyn H. Ellis, M.D. ..... Los Angeles, Calif.
Wendell L. Hughes, M.D. ..... Hempstead, L. I., N. Y.
Lorand V. Johnson, M.D. ..... Cleveland, Ohio
Robert A. Schimek, M.D. ..... Detroit, Mich.
Byron Smith, M.D. ..... New York, N. Y.
William Stone, M.D. ..... Brookline, Mass.
Richard C. Troutman, M.D. ..... New York, N. Y.

Representatives from Eyemakers

Lee Allen ..... Iowa City, Iowa
Roger Alton ..... Southbridge, Mass.
Fritz Jardon ..... Detroit, Mich.
Hugh Laubheimer ..... Chicago, Ill.

STANDING COMMITTEES — *Continued*

Ophthalmic Pathology

Michael J. Hogan, M.D., *Chairman*, San Francisco, Calif.
F. Phinizy Calhoun, Jr., M.D. ..... Atlanta, Ga.
John S. McGavic, M.D. ..... Bryn Mawr, Pa.
Theodore E. Sanders, M.D. ..... St. Louis, Mo.

Otolaryngic Pathology

Paul H. Holinger, M.D., *Chairman*, Chicago, Ill.
David D. DeWeese, M.D. ..... Portland, Ore.
Edmund P. Fowler, Jr., M.D. ..... New York, N. Y.
John R. Lindsay, M.D. ..... Chicago, Ill.
James W. McLaurin, M.D. ..... Baton Rouge, La.
John A. Murtagh, M.D. ..... Hanover, N. H.
George F. Reed, M.D. ..... Boston, Mass.
Ben H. Senturia, M.D. ..... St. Louis, Mo.

Pan-American Relations in Ophthalmology

Conrad Berens, M.D., *Chairman*, New York, N. Y.
James H. Allen, M.D. ..... New Orleans, La.
Moacyr E. Alvaro, M.D. ..... Sao Paulo, Brazil
Victor A. Byrnes, M.D. ..... Washington, D. C.
William B. Clark, M.D. ..... New Orleans, La.
Frederick C. Cordes, M.D. ..... San Francisco, Calif.
Alfred J. Elliot, M.D. ..... Toronto, Ont., Canada
Louis J. Girard, M.D. ..... Oyster Bay, L. I., N. Y.
Erling W. Hansen, M.D. ..... Minneapolis, Minn.
Robison D. Harley, M.D. ..... Atlantic City, N. J.
S. Rodman Irvine, M.D. ..... Beverly Hills, Calif.
Philip M. Lewis, M.D. ..... Memphis, Tenn.
Angus L. MacLean, M.D. ..... Baltimore, Md.
John L. Matthews, M.D., *Secretary*, San Antonio, Texas
Brittain F. Payne, M.D. ..... New York, N. Y.
G. Stuart Ramsey, M.D. ..... Montreal, Que., Canada
Shaler Richardson, M.D. ..... Jacksonville, Fla.
Daniel Snydacker, M.D. ..... Chicago, Ill.
Kenneth C. Swan, M.D. ..... Portland, Ore.
Antonio Torres Estrada, M.D. ..... Mexico, D. F.
Derrick T. Vail, M.D. ..... Chicago, Ill.

Pan-American Relations in Otolaryngology

C. L. Jackson, M.D., *Chairman*, Philadelphia, Pa.
Victor R. Alfaro, M.D. ..... Washington, D. C.
Norton Canfield, M.D. ..... New Haven, Conn.
John Marquis Converse, M.D. ..... New York, N. Y.
Jose Conrad Gros, M.D. ..... Havana, Cuba
Paul H. Holinger, M.D. ..... Chicago, Ill.
Howard P. House, M.D. ..... Los Angeles, Calif.
Carlos Munoz-MacCormick, M.D. ..... Santurce, Puerto Rico
William J. McNally, M.D. ..... Montreal, Que., Canada
LeRoy A. Schall, M.D. ..... Boston, Mass.
Theodore E. Walsh, M.D. ..... St. Louis, Md.

Plastic and Reconstructive Surgery

John Marquis Converse, M.D., *Chairman*, New York, N. Y.
Wendell L. Hughes, M.D., *Co-Chairman*, New York, N. Y.
Crowell Beard, M.D. ..... San Jose, Calif.
William C. Huffman, M.D. ..... Iowa City, Iowa
Dean M. Lierle, M. D. ..... Iowa City, Iowa
Merrill J. Reeh, M.D. ..... Portland, Ore.
Byron Smith, M.D. ..... New York, N. Y.
Edmund B. Spaeth, M.D. ..... Philadelphia, Pa.
A. D. Ruedemann, M.D. ..... Detroit, Mich.

Scientific Exhibit

Kenneth L. Roper, M.D., *Chairman* ..... Chicago, Ill.
Eugene L. Derlacki, M.D., *Co-Chairman*, Chicago, Ill.

Standardization of Tonometers

Peter C. Kronfeld, M.D., *Chairman* ..... Chicago, Ill.
Moacyr E. Alvaro, M.D. ..... Sao Paulo, Brazil
E. J. Ballintine, M.D. ..... Cleveland, Ohio
Bernard Becker, M.D. ..... St. Louis, Mo.
Conrad Berens, M.D. ..... New York, N. Y.
W. Morton Grant, M.D. ..... Boston, Mass.
D. O. Harrington, M.D. ..... San Francisco, Calif.
Thomas H. Hodgson, M.D., Toronto, Ont., Canada
John C. McCulloch, M.D. ..... Toronto, Ont., Canada
Earle H. McBain, M.D. ..... San Rafael, Calif.
John M. McLean, M.D. ..... New York, N. Y.
Adolph Posner, M.D. ..... New York, N. Y.
Robert N. Shaffer, M.D. ..... San Francisco, Calif.

Audio-Visual Education

Dean M. Lierle, M.D., *Chairman*, Iowa City, Iowa
W. L. Benedict, M.D., *ex officio*, Rochester, Minn.
Eugene L. Derlacki, M.D. ..... Chicago, Ill.
Kenneth L. Roper, M.D. ..... Chicago, Ill.
A. D. Ruedemann, M.D. ..... Detroit, Mich.

Teachers' Section

Otolaryngology

Gordon D. Hoople, M.D., *Chairman*, Syracuse, N. Y.
John E. Bordley, M.D. ..... Baltimore, Md.
Lester A. Brown, M.D. ..... Atlanta, Ga.
David D. DeWeese, M.D. ..... Portland, Ore.
James W. McLaurin, M.D. ..... Baton Rouge, La.
Joel J. Pressman, M.D. ..... Los Angeles, Calif.
G. O'Neil Proud, M.D. ..... Kansas City, Kan.
George E. Shambaugh, M.D. ..... Chicago, Ill.

Ophthalmology

A. D. Ruedemann, M.D. ..... Detroit, Mich.
Frederick C. Cordes, M.D. ..... San Francisco, Calif.
John H. Dunnington, M.D. ..... New York, N. Y.
Edwin B. Dunphy, M.D. ..... Boston, Mass.
Lawrence T. Post, M.D. ..... St. Louis, Mo.
Edmund B. Spaeth, M.D. ..... Philadelphia, Pa.
Kenneth C. Swan, M.D. ..... Portland, Ore.
Derrick T. Vail, M.D. ..... Chicago, Ill.

Representatives of the Academy to:

American Association for the Advancement of Science

M. Elliott Randolph, M.D. ..... Baltimore, Md.

American Board of Ophthalmology

Kenneth C. Swan, M.D. ..... Portland, Ore.
F. Bruce Fralick, M.D. ..... Ann Arbor, Mich.
Gordon M. Bruce, M.D. ..... New York, N. Y.
Alson E. Braley, M.D. ..... Iowa City, Iowa

American Board of Otolaryngology

Francis E. LeJeune, M.D. ..... New Orleans, La.
George F. Reed, M.D. ..... Boston, Mass.

American College of Surgeons Board of Governors

Derrick T. Vail, M.D. ..... Chicago, Ill.
Shirley Harold Baron, M.D. ..... San Francisco, Calif.
Harry P. Schenck, M.D. ..... Philadelphia, Pa.

American Committee on Optics and Visual Physiology

Kenneth C. Swan, M.D. ..... Portland, Ore.
Frederick C. Cordes, M.D. ..... San Francisco, Calif.
James E. Lebensohn, M.D. ..... Chicago, Ill.

American Orthoptic Council

John W. Henderson, M.D. ..... Ann Arbor, Mich.
Frank D. Costenbader, M.D. ..... Washington, D. C.
Philip Knapp, M.D. ..... New York, N. Y.

American Standards Association Committee for Standardization of Ophthalmic Lenses

Carl J. Rudolph, M.D. ..... South Bend, Ind.
Arthur C. Linksz, M.D. ..... New York, N. Y.

Alternates

Conrad Berens, M.D. ..... New York, N. Y.
Frank W. Newell, M.D. ..... Chicago, Ill.

American Standards Association Acoustical Standards Board

Gordon D. Hoople, M.D. ..... Syracuse, N. Y.

National Committee on Research in Ophthalmology and Blindness

Bernard Becker, M.D. ..... St. Louis, Mo.
A. Edward Maumenee, M.D. ..... Baltimore, Md.

National Society for Crippled Children and Adults, Inc.

Dean M. Lierle, M.D. ..... Iowa City, Iowa

XIII Jackson Memorial Lecture

THE LENS EPITHELIUM IN THE PATHOGENESIS OF CATARACT

LUDWIG VON SALLMANN, M.D.
BETHESDA, MARYLAND

MAY I say, first of all, what an honor it is for me to be called upon to give a lecture which commemorates one of the great American ophthalmologists. Homage has been paid to the extraordinary qualities of Edward Jackson in the past by most competent speakers, who had known him and his work. Lavish has been their praise and acknowledgment of the man as investigator, physician and teacher, as well as of his contributions to our specialty. I am sorry that I had no opportunity to meet Dr. Jackson personally, but I can add to what has been said before that his name was held in high esteem across the ocean in ophthalmological circles, especially in those eye clinics where refraction problems of a higher order were under study.

My paper today is concerned with a problem almost a century old. What part the lens epithelium plays in the development of cataract, particularly in development of the senile variety, has been the topic of repeated controversy between outstanding ophthalmologists through that century, but no final agreement has been reached. The amazing unfolding of issues dealing with the biochemistry and the metabolism of the lens in the last few decades has not advanced a basis for definite concepts on pathogenesis of cataract, nor have the new studies of submicroscopic lens structures had, as yet, any bearing on the problem. Thus, at the present state of our technical knowledge, examination with the light microscope on a cellular level best lends itself to the attack of pending questions.

In the current work, two lines of approach were selected. In one extensive series of experiments, the effects of one standard dose of an agent injurious to the lens were compared among seven species of laboratory animals. In the second part, the varying sequelae produced by five cataractogenic agents were contrasted in one species. The observations covered prolonged periods but pertained predominantly to those stages which promised insight into what could be termed the early dynamics of pathogenetic events. Information on morphologic detail was obtained by in vivo examination with the slit lamp, by microscopic studies on whole mounts of epithelial preparations, and on histologic sections of the lens. About 1,000 lenses were analyzed in this fashion. For obvious reasons, the manifold results derived from observations on so great a mass of material cannot be incorporated in this paper but will require subsequent detailed reporting.

Before the data of the two main groups of investigations are reviewed, it should be stressed that throughout the

From the Ophthalmology Branch, National Institute of Neurological Diseases and Blindness, National Institutes of Health, Public Health Service, U. S. Department of Health, Education and Welfare, Bethesda, Md.

Presented at the Sixty-First Annual Session of the American Academy of Ophthalmology and Otolaryngology, October 14-19, 1956, Chicago.

study, emphasis was placed on such experimentally induced lens changes as permitted a quantitative breakdown of the results. Alterations of cell division and emergence of cells with signs of nuclear fragmentation caused by the various agents proved suitable for this purpose, whereas other signs of damage, such as proliferation and degeneration of nucleated elements and the occurrence of hydropic and other destructive lesions of the lens fibers, allowed only descriptive analysis. This is true also of the biomicroscopic observations.

Roentgen irradiation with isodoses was the one cataractogenic agent applied to seven species of laboratory animals. Figure 1 depicts the effect of a locally used dose of 1,000 r penetrating x-rays on cell division in the lens epithelium of mice, rats, rabbits, cats, dogs and monkeys. Guinea pigs could not be included. The average number of dividing cells expressed in percentages of the figures obtained from the untreated control eyes is plotted against the time in days after exposure of the eyes to the x-ray beam, with the time scale limited to sixteen weeks. Evidently, in the studied animal species, cell division initially appeared depressed or completely inhibited in all instances, but the extent of this depression varied as well as the period of time before an excessive increase of this cell function took place. The overshooting phenomenon reached the highest peak in dogs and cats; in fact, here, the maxima cannot be shown in the graph.

Another experimentally produced early effect—one of greater pathogenetic importance, I believe—is nuclear fragmentation, or extrusion of chromatin material from the cell. Figure 2 discloses a wide variation in the development of this change between different species. In this instance the counts of degenerate cells comprise the damaged nuclei of the entire lens epithelium at

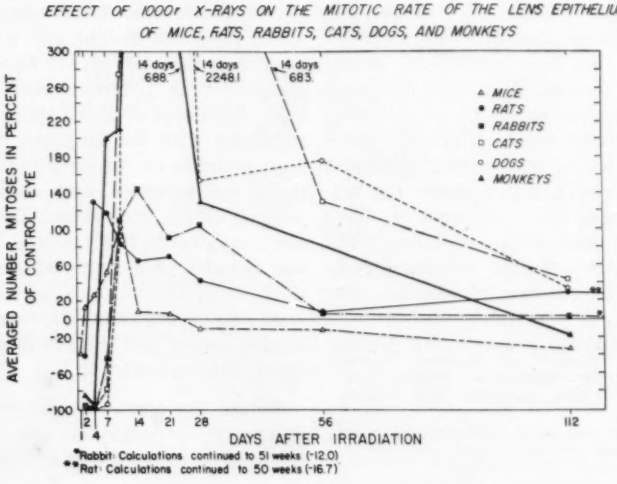


FIGURE 1.

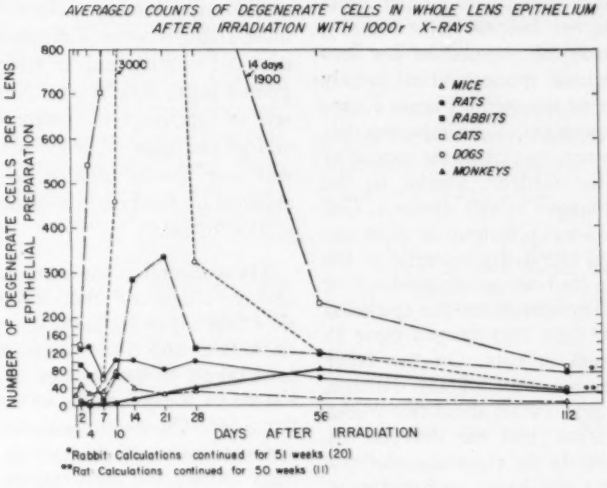


FIGURE 2.

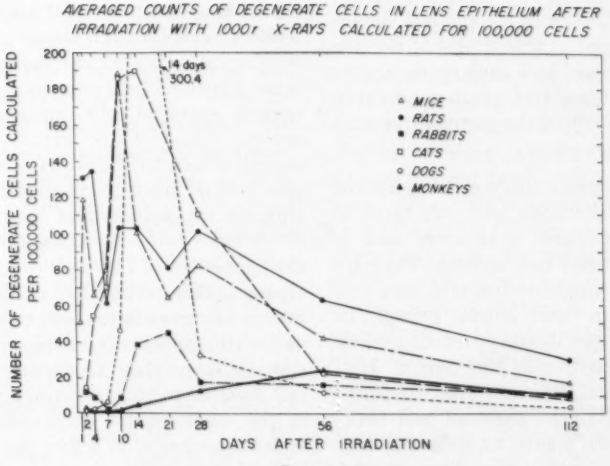


FIGURE 3.

various times after exposure. Data on injury have more meaning for comparison when they are calculated per units of cells; i.e., per 100,000 cells (fig. 3), since the total cell population per lens in the examined species varies greatly with the size of the organ. Figure 3 conveys the impression of an imposing difference between species in the extent of lesions of the nucleus, similar to the graphs of changes in cell division. Cell nuclei in the lens epithelium of dogs and cats extruded chromatin material at the highest rate, and those of monkeys at the lowest. The effects on the epithelial cells of mice and rats ranged close to those observed in cats. On the other hand, appearance time of the damage, the climb to peak values about two weeks after irradiation, and the decrease of the change within the sixteen weeks' period bear out the basic uniformity of the response in the various animal groups. Not recorded in figures 1, 2, and 3 were the observations at the one-year interval obtained from examination of rats, rabbits and guinea pigs. They suggest that the process of nuclear fragmentation induced by exposure of the eye to the 1,000 r of x-rays had almost come to an end at this time, but that the lens epithelium had undergone severe pathologic changes of great polymorphism, particularly in the germinative zone and the bow area.

Initial lenticular opacities were noticed in mice, rats, rabbits and cats three to four months after irradiation, and in guinea pigs after two months. They increased and progressed in mice and rats faster than in other animal groups. In the dog and the monkey, lenses usually remained clear during this period. Histologic studies indicated that displacement of bow nuclei forward and backward and proliferation of epithelial cells from the germinative zone preceded for months the first signs of lens opacification. As a rule, cell proliferation also occurred earlier than swelling and disintegration of lens fibers or the new formation of abnormal nucleated fibers. All these changes were widespread in mice, rats and rabbits, and, in later stages, in guinea pigs; they were minimal or absent in cats, dogs and monkeys. In dogs and guinea pigs, hydrops of lens fibers was not clearly related to structural changes of the bow nuclei or to proliferation of cells.

The assumption has been made by several investigators[3] that ionizing radiation first injures equatorial cells of the epithelium and that opacification as the final result of the damage originates in lesions of the cell nuclei in the germinative zone. The new observations on dog and cat lens epithelia, which outstandingly exhibit the phenomenon of extrusion of Feulgen-positive material from the cell nuclei within two weeks after irradiation without subsequent marked cataractous changes, do not necessarily invalidate this concept. Examination of a series of normal lenses from puppies and kittens revealed that, in contrast to the absence of extruded chromatin in lenses of rabbits a few weeks old, a great number of extruded chromatin globules were dispersed between morphologically normal epithelial cells during the rapid growth phase. These events might be an expression of the effort of the cell to preserve its nucleus-cytoplasm relationship, an explanation that can be applied to the described radiobiological effect on the epithelium of cats and of dogs. These changes, then, differ from the signs of nuclear fragmentation and extrusion of chromatin globules from the cell in other species; here they frequently institute cell death or permanent injury, as shown in the whole-mount preparations made at later intervals. Whether the dissociation of pathologic change in the fibers and damage to the cell nuclei in dogs and guinea pigs denotes a qualitative radio-

biological difference of significance is not clear at the present time. Certainly, the demonstrated graphic illustrations of early radiation injury and the short description of pertinent histopathologic changes intimate a quantitative but not qualitative dissimilarity of the responses. Damage to the nuclei of the surface epithelium in the germinative zone, then, appears to give rise to ensuing pathologic change in the fibers in all examined animal groups.

In the second part of the study, the rat served as experimental animal. The effects of the following five cataractogenic agents were compared: tryptophane, galactose, Myleran®, 1,000 r of x-rays, and alloxan. In view of the similarity of the lens changes induced by galactose and by alloxan, the latter will not be taken up in this presentation.

Tryptophane-Deficiency Cataract

Twelve litters of Sprague-Dawley rats (males, four animals per litter) were placed on the tryptophane-deficient diet of Totter and Day[5] at an age of three weeks; one animal of each litter was used as control. The experimental rats developed cataractous changes when the deficient diet had been continued five weeks. The body-weight gains decreased rapidly with time, and many animals died before lens changes were detected with the biomicroscope. The weights of the globes also were considerably less than those of the control litter mate. The cataractous changes consisted mostly of small specks and fine nets or silky striations in the anterior cortex and slight diffuse opacities in the posterior cortex. Microscopically, the cells of the surface epithelium and the nuclei of the lens bow appeared normal in morphologic detail and spatial arrangement.

An initial moderate fall of mitotic activity was followed by an equally moderate increase of this function, and at the time when cortical opacities developed, a slow decrease of cell mitosis set in (fig. 4). Obviously, then, in this deficiency state the epithelial cells did not exhibit signs of injury which can be incriminated as cause for the evolution of cataractous changes.

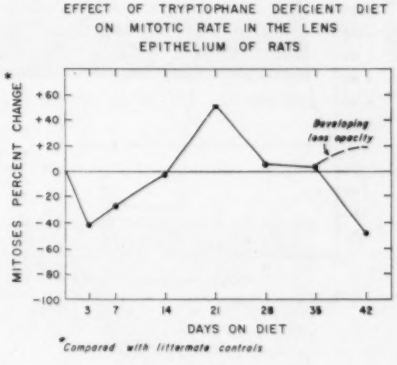


FIGURE 4.

Galactose Cataract

Cataract produced by galactose feeding has been thoroughly studied morphologically and biochemically,[3,1,2] but the relation of fiber damage to epithelial changes has not been investigated or reported. The clinical picture of this cataract is well known. In most instances, when young rats are used, it is characterized by the appearance of a complete or interrupted circle of subcapsular vacuoles in the pre-equatorial zone of the lens. More extensive and progressive changes in the cortical layers follow later. In the present observations on Sherman albino rats, the vacuoles and other less prominent changes were noted about five to seven days after feeding was begun.

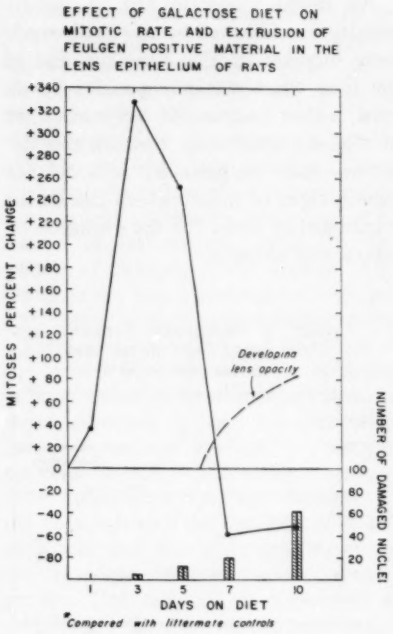


FIGURE 5.

The behavior of the lens epithelium in regard to cell division and cell degeneration is shown in figure 5. The number of dividing cells increased within the first three days and fell to normal values when vacuoles were seen biomicroscopically. Few degenerate cells were counted at this time. Their number rose considerably in the following three days when cataractous changes progressed and cell division was depressed.

In histologic sections, proliferation of nucleated elements was lacking at and behind the equator despite pronounced swelling and vacuolation of lens fibers (fig. 6). This is in clear contrast to the radiation-induced histopathologic changes in the lens. Hydrops of the fibers in the equatorial area and their destruction by huge vacuoles co-existed with normal-appearing nuclei of the uninvolved fibers of the bow at the one-week interval (figs. 7 and 8).

FIG. 6—Swelling and vacuolation of nucleated lens fibers at the equator seven days after galactose diet was started. (× 140)

FIG. 7—Extensive injury to the lens fibers at the equator ten days after galactose diet was started. Rat 113 (× 95)

FIG. 8—As in figure 7. Rat 114 (× 70)

One eye was removed at this time for histologic study, and the galactose diet was discontinued. Clinical recovery from the lenticular opacification in the second eye followed. Seven weeks later, architecture of the bow area was restored almost to normal (fig. 9). Although lenses in this stage contained only circumscribed opacities in the deeper layers of the cortex, broad clefts of proteolyzed fibers usually interrupted the histologic picture, as described by Gifford and Bellows[2] (fig. 10).

It can be concluded from the sequence of intra vitam and microscopically observed changes, first, that the variations in the mitotic rates and the low-grade cell degeneration of the lens epithelium

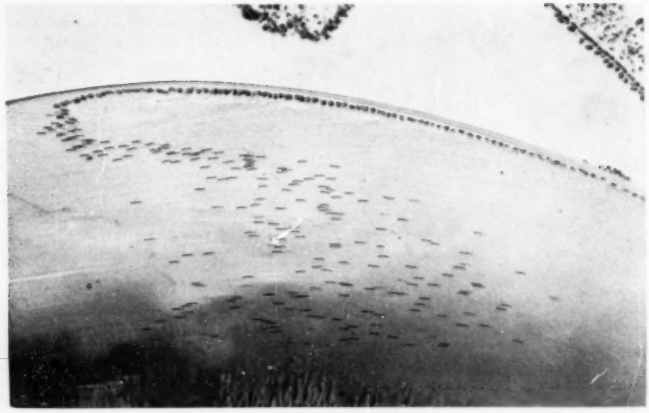


FIG. 9—Restoration of region of lens bow in the second eye of Rat 113, seven weeks after galactose was discontinued. (× 140)

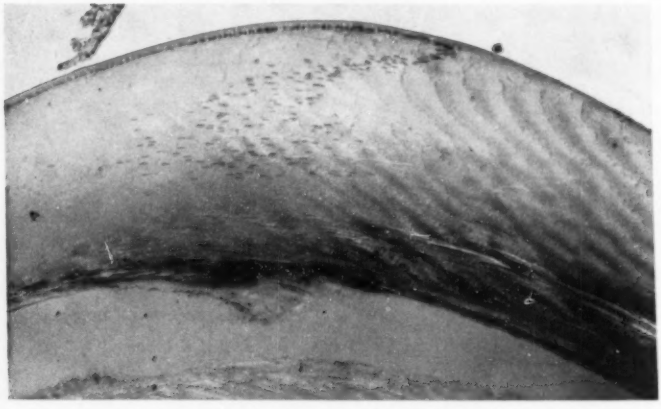


FIG. 10—As in figure 9. Rat 114. Homogenous layer of liquefied fibers in the perinuclear zone not visible with the slit lamp. (× 90)

are not likely to be causally connected with the extensive vacuolation in the equatorial area and, second, that the severe changes primarily involve the cytoplasm of young fibers.

Myleran® Cataract

New information was gained from a systematic study of lens changes produced by feeding young rats small quantities of a sulfonic acid ester known under the proprietary name Myleran. This compound belongs to the radiomimetic chemotherapeutic drugs; it was found effectual in the treatment of chronic myelogenous leukemia. During chronic toxicity studies on Myleran®, workers at the Wellcome Research Laboratories

observed the development of cataract. A preliminary report of the Knapp Laboratory of Columbia University on early histologic changes of the lens was included in the brief description of this cataract by investigators in the Wellcome Laboratories.[4] In the present series, consisting of 72 animals, the initial changes evolved from five to seven weeks after the animals were placed on the diet of Purina fox chow, which contained 15 mg. of Myleran® per kilogram. White dots in the posterior and anterior lens cortex appeared at the same time, often together with net-shaped or diffuse opacities located in the posterior cortical layers. Occasionally, vacuoles were seen in the periphery of the posterior cortex, and in two instances the cataract near the posterior pole was of the bivalve type.

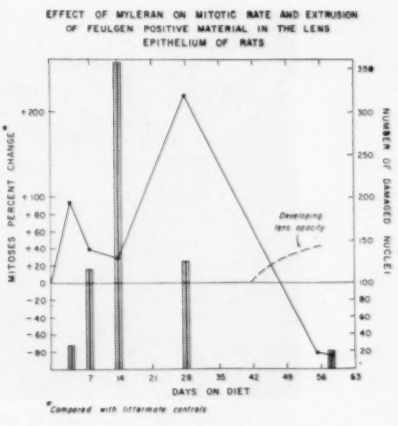

EFFECT OF MYLERAN ON MITOTIC RATE AND EXTRUSION OF FEULGEN POSITIVE MATERIAL IN THE LENS EPITHELIUM OF RATS
MITOSES PERCENT CHANGE*
NUMBER OF DAMAGED NUCLEI
Developing lens opacity
DAYS ON DIET
*Compared with littermate controls

FIGURE 11.

The composite figure 11 again illustrates the effect of the cataractogenic agent on cell division and cell degeneration and also indicates the time relationship between these changes and the development of lenticular opacities. Cell division was not depressed. Initially its rate rose for one week, then at two weeks the curve climbed to a second maximum. The activity remained elevated for about six weeks in all, before it decreased below normal levels in the last weeks of the observation period.

Nuclear fragmentation was a prominent feature. The counts of degenerate cells ascended to a very high figure at the end of the two-week period, and incidence of degenerate cells continued to be high in the following two weeks. The typical forms of extrusion of nuclear material, frequently leading to cell death, were combined with a multitude of degenerative signs, such as anisocytosis with giant nuclei and micronuclei, anisochromia, pathologic mitosis, pycnosis, and loss of the normal pattern characteristic of the various zones of the lens epithelium. Thus, among the agents examined in this study, only Myleran® produced cell degeneration which closely resembled that produced by ionizing radiations. Figure 12 is shown for com-

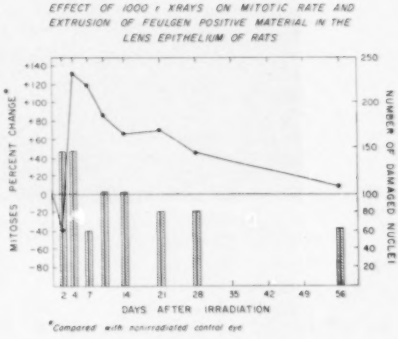

EFFECT OF 1000 r XRAYS ON MITOTIC RATE AND EXTRUSION OF FEULGEN POSITIVE MATERIAL IN THE LENS EPITHELIUM OF RATS
MITOSES PERCENT CHANGE*
NUMBER OF DAMAGED NUCLEI
DAYS AFTER IRRADIATION
*Compared with nonirradiated control eye

FIGURE 12.

parison of lesions produced by 1,000 r of x-rays in rats with those induced by Myleran.® Under the experimental conditions, cataractous changes following roentgen irradiation appeared later than eight weeks after exposure. The microscopic examination of the lenses of My-

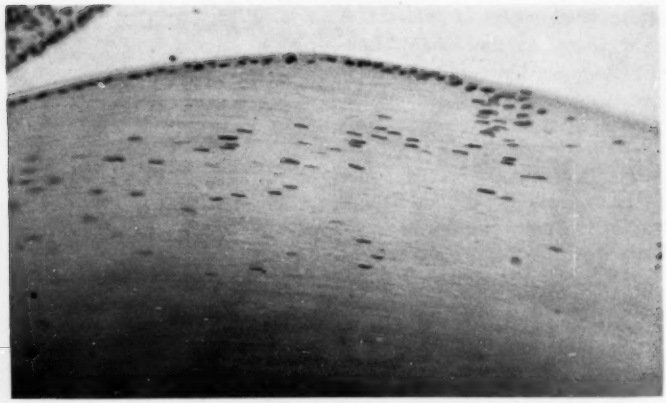


FIG. 13—Moderate displacement of bow nuclei seven weeks after Myleran diet was started. (× 100)

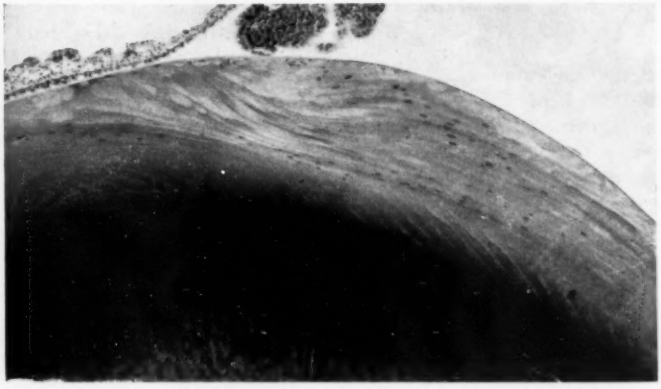


FIG. 14—Moderate displacement of bow nuclei and hydrops of equatorial fibers seven weeks after Myleran diet was started. (× 80)

leran®-fed rats, then, confirmed the observation made on irradiated rats with regard to the presence of pronounced cytologic changes long before opacities were recognized with the slit lamp.

In contrast to the radiation-produced lesions, bow nuclei showed only slight displacement backward about seven weeks after induction of the Myleran® diet (fig. 13). At this time, swelling of lens fibers was often conspicuous. The most important difference between these two types of experimental cataract, however, is the hydropic swelling of the distal ends of superficial lens fibers posteriorly in the absence of migrating cells in the cortical layers, in the experiments with Myleran® (fig. 14). This damage appears to be the substrate of the clinically seen diffuse opacities around the poste-

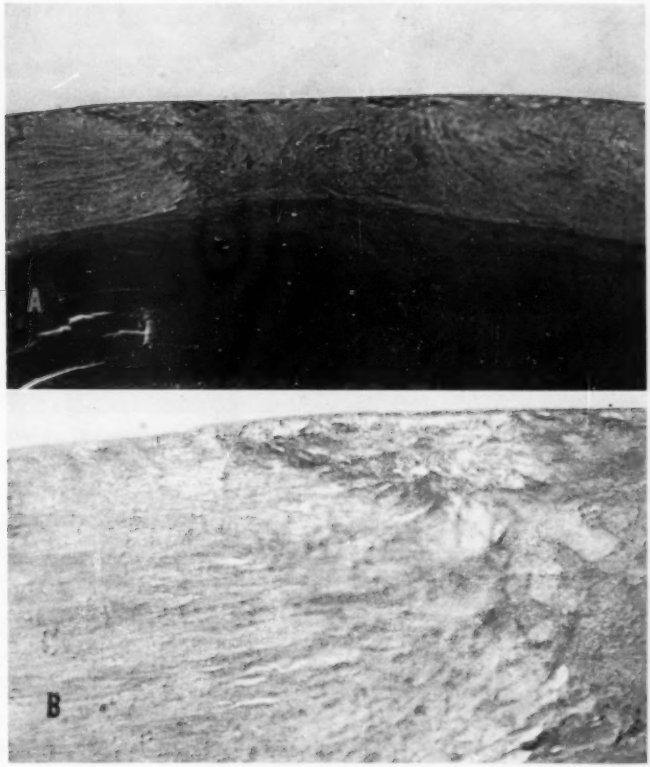


FIG. 15—Hydropic swelling of posterior ends of superficial lens fibers in the absence of migration of cells, seven weeks after Myleran diet was started. (A) (× 100); (B) (× 550)

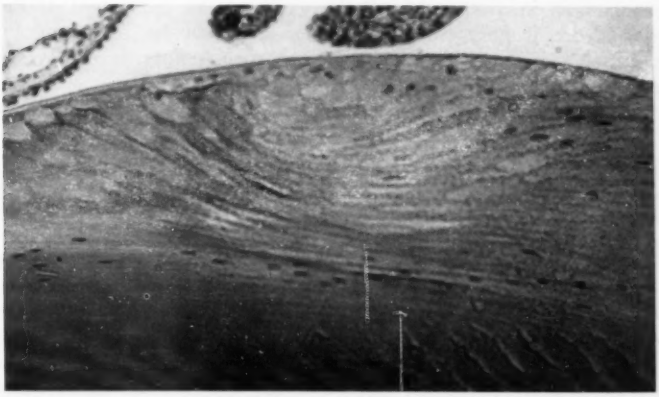


FIG. 16—Displacement of deep equatorial fibers by swollen superficial fibers, seven weeks after Myleran diet was started. (× 140)

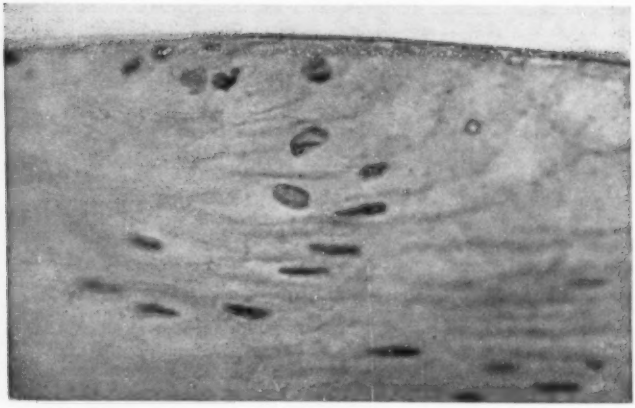


FIG. 17—Degeneration of bow nuclei seven weeks after Myleran diet was started. (× 440)

rior pole (fig. 15, A and B). Hydropic fibers at the equator affected the architecture of the bow area as they displaced deeply situated normal fibers and disarranged the spatial distribution of the bow nuclei (fig. 16). Degenerative changes in the bow nuclei are shown in figure 17.

The described observations on the rats given Myleran® point to a severe early injury of the lens epithelium and, probably independent of this lesion, to extensive changes in young nucleated lens fibers. Hydropic fiber swelling set in at the equatorial area and, after a short time, led to swelling at the distal ends of the fibers near the posterior pole. The bivalve appearance of the cataract in a few experiments was not connected with migration of damaged epithelial cells, from which, in radiation cataract, freak lens fibers originate.

COMMENTS AND CONCLUSIONS

It is fully realized that any approach to the cataract problem which pertains to cellular and tissue morphology alone is very incomplete by nature, but at present the succession of experimentally induced lesions in the lens tissue can be followed best by microscopic studies. In this paper a fairly wide survey on cytologic, histologic and biomicroscopic changes of the injured lens provides certain guidelines relative to cataractogenesis in man.

1. Biological consequences of x-ray radiation in the lens have been found to be fundamentally similar in the seven studied animal groups, despite great variations in the extent of the lesions. Species with the lowest mitotic activity in the epithelium were slowest in showing damage of tissue elements of the lens. Estimates of cell division in the clear human lens lack accuracy. From one to ten dividing cells were counted in eight such lenses, but local or general anesthesia or the lapse of time after death of the patient obviously affected the counts. By extrapolation of experimental data, it can be assumed that primary damage to the cell nuclei in the germinative zone and migration of cell elements from this area, or displacement of cell nuclei from the bow, occur also in the irradiated human lens. The innate

tendency of this lesion to stay quiescent for long periods and usually to progress at a slow rate are well-known characteristics of radiation cataract of man.

2. Experimental galactose cataract also has its correlate in human lens pathology. Recovery from lens damage in this instance can be explained by the moderate involvement of the cells in the germinative zone and by the transposition of extensively injured fibers to deeper layers by healthy young fibers. The damaged fibers give rise to inconspicuous residual opacities.

3. Myleran® cataract of the human eye has not been reported, but systematic studies on patients treated with the compound for chronic myelogenous leukemia have not been carried out. From the experiments on rats, it is to be expected that such cataracts would not easily regress, although they may be so slow in onset and development that opacities cannot be observed at all during the short life span of such patients. Attention should be drawn to this cataract, nevertheless, because its qualities make it well suited for microscopic, histochemical, or metabolic studies.

4. Cataract formation in tryptophane-deficient rats is an example of the development of opacities in lenses with an apparent normal epithelium. Further studies are necessary to show whether or not the underlying fiber changes disappear in time, when the rats are again placed on a normal diet, as do those in cataract induced by galactose when the drug is withdrawn.

Coming back to the principal subject of this investigation, which is concerned with the pathogenetic significance of lens epithelial changes in cataract development, it is felt that a distinction has to be made between lenticular opacities produced by ionizing radiations and by radiomimetic drugs and those resulting from the administration of the three other cataractogenic factors studied. In the first case, damage affecting the cell nuclei in the germinative zone appears to initiate the series of pathologic events which finally lead to cataractous lesions. Usually these changes are not reversible and, as a rule, tend to progress. On the other hand, in galactose cataract, in alloxan cataract, and in cataracts caused by tryptophane deficiency, the lens epithelium in the germinative zone is but little involved with the exception of its mitotic activity. This effect on cell division does not seem to contribute to the extensive lens fiber changes. New normal lens fibers are formed upon withdrawal of the injurious factors, and residues of the damage are confined to circumscribed layers of the lens cortex.

The first part of the reported work was carried out with the assistance of Mr. Leo Caravaggio, Miss Carmen Munoz, and Miss Ann Drungis, and the second part with the assistance of Mr. Caravaggio and Miss Patricia Grimes.

Dr. E. J. de Beer of the Wellcome Research Laboratories kindly provided us with 1,4-dimethanesulfonoxybutane (Myleran) for use in these studies.

REFERENCES

1. Friedenwald, Jonas S., and Rytel, Dolores: Contribution to the histopathology of cataract, A.M.A. Arch. Ophth., 53:825-831 (June) 1955.
2. Gifford, S. R., and Bellows, J.: Histologic changes in lens produced by galactose, Arch. Ophth., 21:346-358 (Feb.) 1939.
3. Nordmann, Jean: Biologie du Cristallin, Paris, Masson et Cie, 1954, pp. 402-418, 468-474, 569-573, 599-604.*
4. Solomon, Cyril; Light, Amos E., and de Beer, E. J.: Cataracts produced in rats by 1,4-dimethanesulfonoxybutane (Myleran), A.M.A. Arch. Ophth., 54:850-852 (Dec.) 1955.
5. Totter, John R., and Day, Paul L.: Cataract and other ocular changes resulting from tryptophane deficiency, J. Nutrition, 24:159-166 (Aug.) 1942.

*The reader is referred to the extensive bibliography on radiation and galactose cataract and cataract produced by tryptophane deficiency contained in this book.

* * *

PART I

DELAYED RESTORATION OF THE ANTERIOR CHAMBER
SECONDARY GLAUCOMA
IRIS INCARCERATION AND PROLAPSE
CORNEAL EDEMA

JOHN M. MCLEAN, M.D.
NEW YORK, NEW YORK

Delayed Restoration of the Anterior Chamber

AT the end of an uncomplicated lens extraction, the anterior chamber is absent. It is, however, re-formed and fairly deep by the time the first dressing is done on the next day unless something is amiss, and it should remain deep thereafter.

CAUSES

The various factors which may be blamed for delayed re-formation or subsequent collapse of the chamber may be listed as follows:

Leaking Wound

By far the commonest cause of flat chamber is leakage of aqueous from the incision. This situation may be the result of several mechanisms.

A. Inadequate closure

Failure to secure water-tight approximation of the wound edges by properly placed multiple corneoscleral sutures is now much less common than formerly, but it still heads the list of factors which may cause a leaking wound. So much has been said and written about firm wound closure[6,16,19] that it need not be reviewed here.

B. Suture placed too deeply

In an effort to assure solid closure, the surgeon occasionally inserts a corneoscleral suture so deeply in the lips of the wound that it serves as a wick through which aqueous may filter and thus keep the chamber decompressed.[7,12] This situation may result in a failure of the chamber to re-form or, more often, in late collapse or shallowness. Leakage is probably more common along deep silk sutures, which serve as wicks, than along gut sutures, which tend to swell and plug the potential leak.

C. Wound incarceration

Inclusion of extraneous material, such as iris and lens capsule, may also serve as a source of leakage.

D. Trauma

Trauma to the eye at any time before solid healing has taken place may loosen

From the Department of Surgery (Ophthalmology), New York Hospital—Cornell Medical Center.

Presented at the Sixty-First Annual Session of the American Academy of Ophthalmology and Otolaryngology, Oct. 14-19, 1956, Chicago.

the wound edges enough to cause the chamber to collapse. Such a situation is apt to be temporary, and it is self-rectifying in most instances.

Suppression of Aqueous

A. Surgical shock

It has been suggested from time to time that the shock of operation and sudden ocular decompression may result in failure of aqueous formation. Kronfeld[10] has supplied some recent evidence to back up this theory. If aqueous formation is arrested, obviously the chamber cannot re-form normally and will remain flat until a supply of fluid is available. The frequency of occurrence of this mechanism, if it occurs at all, remains to be demonstrated.

B. Pharmacologic suppression

It is also theoretically possible that if a patient is under carbonic anhydrase inhibitor therapy, there might be sufficient suppression of the aqueous to result in delayed chamber re-formation. I have never recognized such a case.

Choroidal Detachment

Detachment of the choroid is a frequent, and possibly constant, accompaniment of surgical decompression of the eye. It is more likely that choroidal detachment is the *result* of hypotony and shallow chamber, but it is often cited as a causative factor. It has been suggested that detachment is a result of supraciliary leakage of aqueous. Choroidal detachment is frequently seen in soft eyes without flat chamber, and flat chamber may be seen in hard eyes without choroidal detachment. It would seem, therefore, that detachment of the choroid is unfairly incriminated.

Vitreous Edema

Edema of the vitreous body has been suggested as a possible cause of flat chamber.[21] If this be the case, one would expect a hard, rather than soft, eye and absence of detachment of the choroid, which is usually present.

RESULTS

The result of delayed re-formation of the chamber depends on several factors. The most important of these is time. If the chamber is re-formed in four to five days, convalescence almost invariably proceeds uneventfully. Indeed, if other factors are favorable, a chamber may remain flat for some time longer with no untoward event. The second factor is the amount of postoperative inflammation. The less inflamed the eye, the longer a flat chamber can be tolerated; the more inflamed it is, the more likely are complications to ensue. The third factor is the state of the ocular tissues, particularly the posterior surface of the cornea. The healthier these structures are, the less serious is persistently flat chamber. The more they are traumatized or diseased, e.g., by corneal endothelial dystrophy, the more serious is the condition. When the combination of these factors is unfavorable, the following complications might result:

Peripheral Anterior Synechias

Delayed reseparation, by aqueous, of the iris root from the back of the cornea often results in peripheral adhesions, which may so block the angle as to produce postoperative glaucoma of greater or less severity (fig. 1). This train of events was clearly demonstrated only when gonioscopy became popular.[11,14]

Corneal Edema and Vitreous Adherence

Transient edema of the cornea, which frequently accompanies flat chamber, is not of itself of serious import. It may, however, signify that adhesions are be-

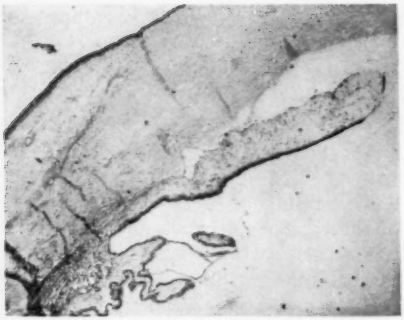


FIG. 1—Anterior peripheral synechia causing secondary glaucoma after flat anterior chamber.

ginning to form between vitreous and cornea. The adhesions, in turn, can result in a persistently irritable eye with progressive corneal haze and visual impairment. Such changes are more likely in the presence of unhealthy endothelium,[8] but they may occur when no such disease has been recognized if contact is allowed to last too long.

Iris-Vitreous Adhesions

When the iris is compressed between vitreous and cornea, it is usually hard to move the pupil with drugs, and various adhesions may take place. Posterior synechias to vitreous face or posterior capsule, if such remains, may result in cosmetic and visual impairment. Ring synechia to an intact hyaloid may be the beginning of pupillary-block glaucoma.[5] A rigidly held small pupil may become filled with inflammatory membrane or hyaloid condensation, eventually requiring further operation for visual restoration.

PROPHYLAXIS

Prophylaxis against flat chambers was implied in the foregoing list of causes. Of prime importance is accurate and tight reapproximation of the wound edges. Implicit in such closure is meticulous toilet of the wound to avoid any incarcerations. If ciliary atony as the result of trauma can be considered a cause of delayed restoration of the chamber, it is further argument for delicate handling of tissues. Probably aqueous inhibitors should be avoided at the time of cataract surgery.

Refilling of the chamber at the end of operation, especially by air, has been offered as a preventive for flat chamber. After using it routinely for several years, I abandoned this as an unnecessary extra maneuver in the presence of sound wound closure.

TREATMENT

Treatment of the delayed or collapsed chamber has been the source of much discussion. Some of the methods which have been advocated may be considered briefly.

Watchful Waiting

Until the chamber has remained flat for at least five days, no radical steps need be taken. If postoperative inflammatory reaction is minimal and if the anterior segment tissues are known to be healthy, a longer period is probably safe. The use of miotics during this period may help to prevent peripheral synechias or iris incarceration before a small leak closes. Their use is often accompanied by prompt refilling of the chamber, but how much credit should be given the miotics and how much to coincidence will continue to be debated.

Repair of Leaking Wound

An obvious leak or one demonstrable by fluorescein should of course be repaired by suturing, with careful inspection for any incarcerated material. The fluorescein test is often facilitated by ultraviolet illumination.

Air Injection

When the leak cannot be demonstrated, injection of enough air to fill the chamber is usually indicated as soon as the safe waiting period is over. This is best done through a small beveled puncture made with a discission knife away from the wound, or with an Amsler needle. Air usually blocks a small leak much better than liquid and allows the defect to heal while the air is being absorbed and replaced by aqueous.

Sclerotomy-Sclerectomy

Some surgeons prefer to combine air injection with posterior sclerotomy or sclerectomy over the area of greatest choroidal detachment.[4,12] This procedure is more formidable and, in our experience, rarely necessary. We prefer to reserve it for the occasional case in which air injection alone fails.

Removal of Deep Suture

When an overly deep suture is recognized or suspected as the cause of leakage, its prompt removal is in order. Removal is usually followed by prompt restoration.

Acetazoleamide (Diamox®)

The use of carbonic anhydrase inhibitors in cases of flat chamber has been reported.[21] The theory on which this therapy is based is that the causative vitreous edema is thereby relieved. In our limited experience with delayed re-formation, we have tried this method and found it wanting. In fact, in the first case in which Diamox® appeared to work, we subsequently discovered that, through error, the nurse had failed to administer the medication!

Cautery

Cauterization by thermal or chemical means is occasionally recommended for a leaking wound. This approach seems so contrary to good surgical principles that we have had no experience with it and do not expect ever to have occasion to use it.

Secondary Glaucoma

Secondary increase in tension after cataract extraction can be a very distressing and serious outcome. It may vary from severe, painful, rapidly disabling disease to low-grade, asymptomatic, but nonetheless sight-destroying hypertension. The latter form may be overlooked unless the surgeon has a high index of suspicion and careful postoperative follow-up is made.

CAUSES

Peripheral Anterior Synechias

The mechanism of peripheral iris adhesions from prolonged nonformation of the anterior chamber has just been discussed.

Iritis

Postoperative iritis, including that caused by retained lens material, foreign material and infection, will be covered in the next section of this symposium.

Epithelial Downgrowth

The very serious problem of epithelium growing in from the wound and pro-

ducing intractable secondary glaucoma will be covered in detail in another section of the symposium.

Hemorrhage

Hemorrhage in the anterior chamber, when sufficiently large and when the blood is slow in absorbing, can cause some elevation of tension which may be transient or may persist (fig. 2). Massive deep bleeding can have a similar result.

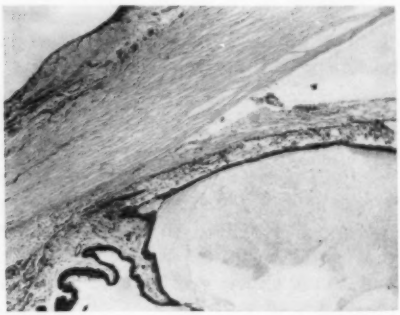


FIG. 2—Fibrotic angle closure following persistent postoperative hyphema.

Pupillary Block

Glaucoma from blockage of the pupil by a plug of vitreous has been mentioned above in connection with flat chambers. It may also occur without antecedent delay in chamber restoration.

Unrecognized Primary Glaucoma

It is always possible that the patient may have had low-grade primary glaucoma which was not discovered before the cataract extraction. Such disease may be mistaken later as postoperative secondary glaucoma. It is also possible that mild open angle primary glaucoma may be worsened by impairment of the outflow channels through scarring of the incision. Whether this actually takes place has not, to my knowledge, yet been clearly demonstrated. We are presently engaged in a study of outflows before and after cataract sections of different types to try to clarify this matter.

RESULTS

The results of postoperative secondary glaucoma are well known. While it has sometimes been said that the aphakic eye can support slightly higher tension than the phakic, any considerable increase in pressure results in the well recognized signs and symptoms with loss of field and vision (fig. 3).

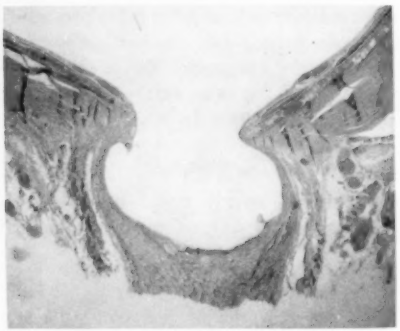


FIG. 3—Deep cupping of disc in aphakic secondary glaucoma.

PROPHYLAXIS

Prophylactic measures include the prophylaxis and treatment of flat chamber, as discussed above, the recognition and treatment of postoperative inflammation, and the insurance against hemorrhage or epithelial downgrowth which is given by firm and meticulous wound closure. Adequate communication between anterior and posterior chambers should avoid the problems of pupillary block, but this does not necessarily imply a full iridectomy. If further investigation supports the hypothesis that scleral or deep limbal sections cause

diminution of aqueous outflow, then diminished or border-line coefficient of outflow may be an indication for shallow or purely corneal section.

TREATMENT

Once glaucoma is established, there are many approaches to treatment, those in the early stages depending on the causative factors, the later ones being less specific.

Evacuation of Blood or Cortex

Persistently unabsorbed hemorrhagic blood which is causing glaucoma and fails to yield to conservative treatment may, in rare instances, require surgical removal.[4] When blood has been evacuated, it is advisable to reinflate the anterior chamber with air lest a too sudden drop in pressure result in further bleeding. Presence of blood is a contraindication to steroid therapy, for there is evidence that steroids delay absorption.[1] Retained lens material which is causing ocular hypertension may also require evacuation. This subject will be discussed more fully later in the symposium.

Management of Iridocyclitis

The treatment of anterior uveitis which is causing a rise in pressure will also be dealt with in the next section. It may include nonspecific adrenal steroid therapy which can, in certain combinations of circumstances, result in reduction of early acute secondary glaucoma.

Treatment of Epithelial Downgrowth

The management of epithelial invasion of the anterior chamber will be covered in detail in a later section of the symposium. Both surgery and radiation are available tools, but early recognition of this potentially disastrous complication is important.

Nonsurgical Management

When glaucoma is definitely established and the primary causative factors can no longer be attacked, the problem resolves itself into direct management of the ocular hypertension itself. In the medical management, miotics have a prominent place, particularly di-isopropyl fluorophosphate, which has its best application in the aphakic eye. One important exception to use of miotics is glaucoma due to pupillary block. Such glaucoma is exaggerated by miosis, and presence of pupillary block is an obvious indication for mydriatics. Acetazoleamide may also be very useful in both the early and late phases. It has been the subject of so many recent reports that further elaboration here would be redundant.

Surgical Management

The surgical approach to established secondary glaucoma is always in order when other methods have failed or are impracticable for various reasons. The available methods fall into three classes.

A. Correction of blocked circulation

In cases of pupillary block, the problem centers around restoration of intraocular fluid circulation. Iridectomy,[4] either full or peripheral, is the operation of choice. Simple iris puncture with a needle-knife, iris transfixion, and discission of a vitreous "mushroom" are also possibilities, but they are not as highly recommended. Unless intraocular circulation is restored promptly, synechias may form in numbers sufficient to make these methods alone inadequate.

B. Supplemental outflow channels

In all other cases of secondary glaucoma, the problem is one of inadequate outflow. This is usually met by creation of additional drainage avenues. Cyclodialysis has its best application in the aphakic eye and is usually considered

the operation of choice. There are several modifications of technique. One of these that deserves special mention is the use of air as an added preventive of bleeding. The external filtering operations are also useful but are less popular because of potential vitreous loss, vitreous plugging of the filtering wound, and the inefficiency of a bleb at an already scarred limbus.

C. Aqueous suppression

Since even cyclodialysis, the preferred operation, leaves much to be desired, operations to reduce aqueous formation have been used increasingly in recent years. Cyclodiathermy,[3] retrociliary diathermy, and cycloelectrolysis[2] all have their advocates and are all theoretically good in balancing the diminished outflow with decrease in inflow. In our hands, none of these has been as useful as cyclodialysis. The results are so often temporary. We have also seen in consultation several disastrous results in which overenthusiastic destruction of the ciliary body has resulted in loss of the globe.

Iris Incarceration and Prolapse

Incarceration and frank prolapse of iris as complications of cataract extraction are seen with decreasing frequency as wound closure constantly improves. The usual causes follow.

CAUSES

Inadequate Reposition

There would seem to be little excuse for leaving iris in the wound at the end of operation, but this error does occasionally occur. Good akinesia and anesthesia allow deliberate, careful toilet of the wound. There should be no need for rapid, panicky closure even if vitreous has been lost. The danger of catching a strand of iris in closing deep corneoscleral sutures must be kept in mind.

Insecure Closure

Inadequate wound closure as a source of wound leakage has been discussed in the early portions of this paper. Iris tissue may become incarcerated in or prolapsed through such a leaky wound at any time in the postoperative period.

Trauma

Just as trauma may spring the wound and allow the chamber to collapse, so, too, it may allow the gush of aqueous to carry iris tissue into the wound with it.

Simple Extraction

The omission of any iridectomy or iridotomy may be a contributing factor in making it easier for iris to be carried into a weak spot in the wound.

RESULTS

The results of iris incarceration or prolapse may be many. The first two have already been considered: flat anterior chamber and secondary glaucoma (fig. 4).

Iritis

This result of iris incarceration will be covered in the next section of the symposium.

Sympathetic Ophthalmia

This disastrous outcome, although rare, merits separate consideration.

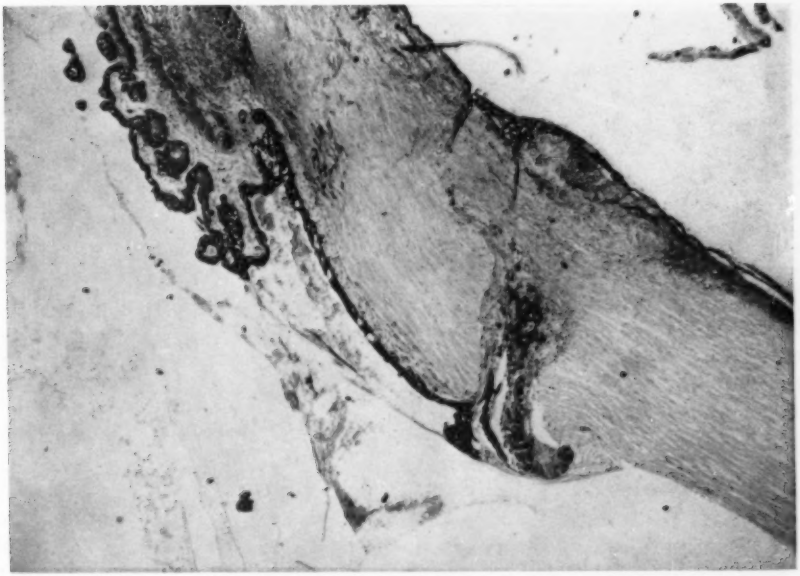


FIG. 4—Iris prolapse causing anterior peripheral synechia and glaucoma.

Infection

Purulent infection does not often enter the eye through an iris prolapse, but an exposed prolapse can serve as portal of entry for bacteria (fig. 5). This unhappy outcome, too, will be considered in a later section.

Hypotony

The artificial external drainage which the unintentional iridotasis incident to iris prolapse can produce, rarely results in hypotony. When it does, macular edema, engorgement and edema of the nerve head, detachment of the retina, and atrophy of the globe are possible end results (fig. 6).

Ectopic Pupil

Even slight iris incarceration usually results in decentering of the pupil. Larger incarcerations or prolapses may be responsible for marked displacement, hammock pupil, or even complete loss of visual pupillary aperture.

High Astigmatism

Least serious of the end results of iris incarceration, although potentially very annoying, is uncommonly high, usually oblique, and sometimes irregular astigmatism. I have seen as much as thirteen diopters of cylinder resulting from this cause.

PROPHYLAXIS

The prophylaxis of iris inclusion lies primarily in good and secure wound closure. This has already been considered. Careful wound toilet, avoidance of pressure, and corneoscleral suturing which is both adequate and accurate cannot be overstressed. Protection of the eye against postoperative trauma is an

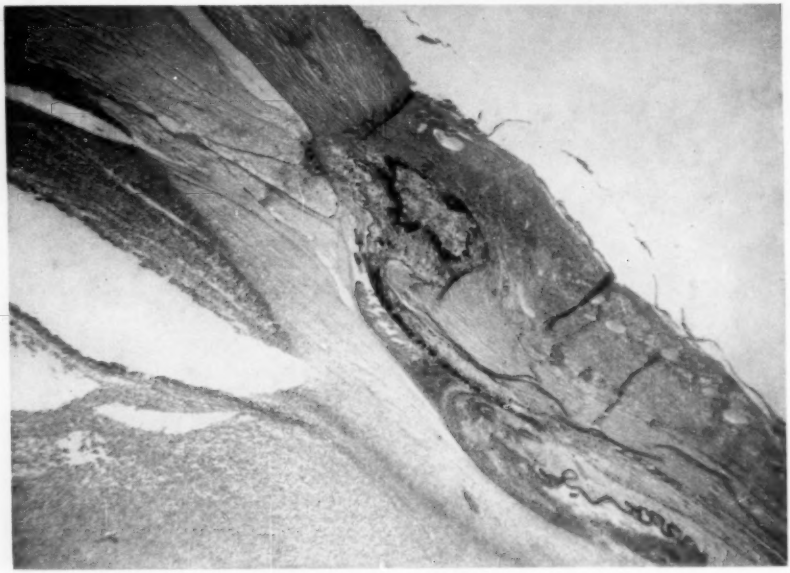


FIG. 5—Postoperative infection entering at iris prolapse.

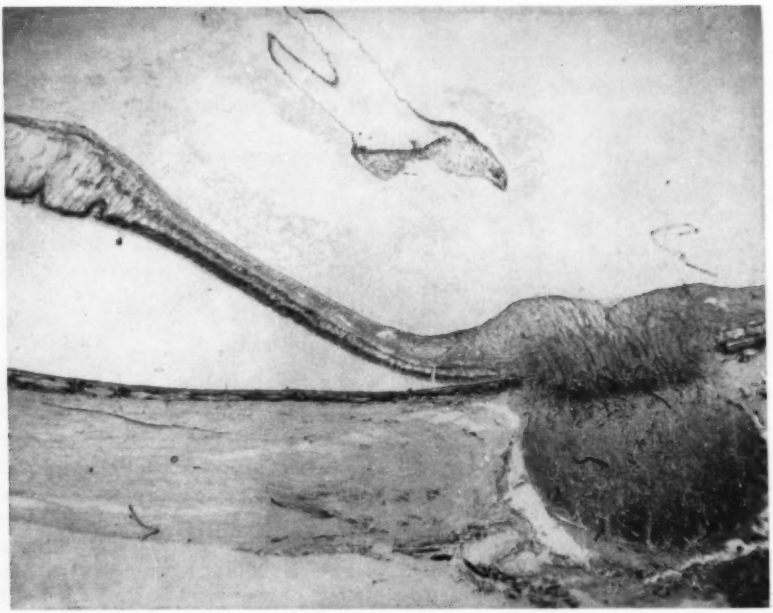


FIG. 6—Edema of disc and retina with cystic changes in macula following severe prolonged hypotony.

obvious measure in the prophylaxis of iris prolapse. This does not mean that the patient must be kept in bed if his wound is solidly closed. A peripheral iridectomy, at least, is a worth-while preventive measure except in those special cases in which it is contraindicated and its omission is countenanced as a calculated risk.

TREATMENT

Treatment of incarceration or prolapse must always be considered. The only question in small incarcerations is how extensive to make the treatment.

Pharmacological Treatment

In a small incarceration that is recognized promptly, it is probably worth while to attempt restoration by drugs alone. The early use of strong miotics to contract the sphincter forcibly, coupled with use of adrenergic drugs to tighten the dilator fibers, will sometimes result in replacement of the iris tissue. This therapeutic measure is so simple and so benign that it is probably always worth attempting.

Observation

If attempts at repair of a small incarceration with drugs fail, it is sometimes wiser not to take further steps unless the situation worsens, provided prolonged flat chamber does not ensue. This conservative approach may even be used on a small prolapse if it is well covered by conjunctiva.

Re-placement

The iris tissue involved in an early incarceration or a covered prolapse may be re-placed successfully under favorable circumstances. This maneuver is safer if it is accompanied by peripheral iridotomy at the site, additional wound suturing, and insufflation of the chamber with air.

Excision

All exposed prolapsed tissue, any replaced tissue that has again prolapsed, any tissue that has remained prolapsed for significant time periods, or other prolapsed tissue that threatens to incur the serious outcomes mentioned above, merit excision. The excision should be complete, clean, prompt and reinforced by further suturing. Surgical excision is always to be recommended when there is doubt about what procedure to adopt.

Cauterization

The use of a cautery, either thermal or chemical, on prolapsed iris tissue is mentioned only to condemn it. While there have been reports of successful cautery treatment of iris prolapse, too many eyes have been lost by this maneuver to permit its approval. Worse than the cases in which the aphakic eye alone was lost are the authenticated cases of sympathetic ophthalmia resulting from cautery of prolapsed iris.

Antibiotics

Since any iris prolapse is a potential source of intraocular contamination, it should always be treated with proper antimicrobial agents.

Sympathetic Ophthalmia

The nightmare of all ophthalmic surgeons, sympathetic ophthalmia, can and does follow cataract operation (fig. 7). Fortunately the incidence is very, very low, but it always can happen. Potential contributing factors include iris pro-

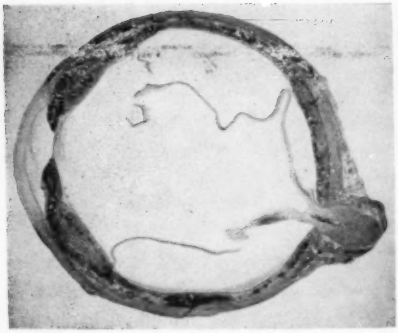


FIG. 7—Sympathetic ophthalmia following cataract extraction.

lapse, ruptured wound, expulsive hemorrhage, and overly traumatic surgery. Sometimes the cause is obscure.

PROPHYLAXIS

Prophylaxis includes careful operative techniques with all possible precautions for safety and minimal trauma to tissues. Prompt recognition and repair of iris prolapse and wound rupture are important preventive steps. Recognition of a hopelessly lost eye and early enucleation of such an eye to protect the other eye are bitter pills for the surgeon and the patient, but they are very necessary parts of good cataract surgery. In answer to a question which is repeatedly asked, there is no evidence of which I am aware that prophylactic use of adrenocorticosteroids has any value.

TREATMENT

Treatment, once the disease has struck both eyes, does not include plucking out the eye that offends thee, if it has potential vision. Enucleation is of value for prophylaxis only. If the disease is underway and if the inciting eye is aphakic, it may, in the long run, be the better of the two. Until further knowledge of this entity is gained, the treatment of choice is intensive systemic therapy with adrenal steroids.[17] Local application alone is inadequate.

Corneal Edema (Early)

Early postoperative corneal edema is often more annoying than serious. Late corneal edema, to be considered subsequently, is of more serious import. The causes of early postoperative edema of the cornea may be considered.

CAUSES

Corneal Trauma

Trauma to the cornea, particularly its endothelial surface, must be considered the most common cause of edema.[9] Trauma due to rough handling or to abrasion of the inner face with rough-surfaced or roughly handled instruments may be unavoidable, but it should be kept to a minimum. Chemical trauma is less common, but occasionally the anterior chamber may be irrigated with solutions of improper tonicity or solutions containing irritating chemicals. Thermal trauma is rare, for fortunately the custom of flaming instruments before introducing them into the eye is not prevalent in this country.

Vitreous Adhesions

If the vitreous sticks to the cornea, edema and clouding may ensue.[13] Such a sequence of events may be the result of a persistently flat anterior chamber or

FIG. 8—Fibrotic scar at site of adhesion of vitreous to cornea.

pupillary block (both of which have already been considered) or, rarely, just excessive mushrooming of the hyaloid through the pupil. It may also follow vitreous loss with the incarceration of formed vitreous in the wound (fig. 8).

Endothelial Disease

Disease of the endothelium, such as Fuchs's dystrophy, is not usually responsible, alone, for early corneal edema unless edema existed before surgery. However, it may make the inner surface more susceptible to trauma or vitreous adhesion and thus be a contributing factor. The important changes from endothelial dystrophy are classed with late corneal edema and will be considered under that section.

Glaucoma

Early postoperative rise in tension may, of course, result in early corneal edema. Postoperative glaucoma has already been considered.

RESULTS

The results of early edema are rarely serious. Most often the causes, such as operative trauma, are self-limited, and the edema is transient and reversible. If the edema persists, as it may with vitreous adherence, permanent opacity may result. Such situations should be rectified early. If the edema represents aggravation of a pre-existing dystrophy, the situation may be permanently worsened.[15] If it is a sign of early glaucoma, it is of secondary importance in itself. If it acts to call attention to an unrecognized rise in tension, it is serving a useful purpose.

PROPHYLAXIS

The prophylaxis of early edema consists, first and foremost, in the avoidance of corneal trauma. All instruments for introduction into the chamber should be smooth-surfaced, with high polish. Intracameral instrumentation should be kept to the necessary minimum. Contrary to popular opinion, it is much easier on the cornea and safer for the eye to open the wound widely for maneuvers than it is to slide instruments forcibly along the back of the cornea. Care, too, should be taken to have all solutions nonirritant. Early repair of flat chamber, iris prolapse, and pupillary block may be listed as prophylactic against corneal edema but should be undertaken also for more compelling reasons. Finally, clearing of any formed vitreous from the incision can be listed. I have heard it said that many of these difficulties could be avoided by returning to the more deliberate extracapsular operation. However, these complications are so uncommon in the properly executed intracapsular extraction and the other advantages are so overwhelming that I cannot agree with the implication.

TREATMENT

Treatment is not often complicated. In most cases, patience is rewarded by the disappearance of early edema as the cornea recovers and returns to normal. The surgeon may delude himself into

thinking that whatever drops he has instilled into the eye are responsible for what would have happened without them. When vitreous contact is responsible, early air insufflation of the chamber is in order before firm adhesion has formed. It is then often advisable to keep the patient so positioned that the air bubble maintains separation until adequate aqueous has ensured permament freedom. It is possible that in otherwise uncorrectable cases of early edema which do not resolve, the use of Diamox®, as Stocker[20] has used it in corneal dystrophy, may be of value. Persistent edema from serious corneal trauma may eventually result in enough opacification to call for transplantation. Edema from vitreous adhesion which can not be separated by air injection may indicate mechanical separation by a maneuver resembling cyclodialysis.[18]

REFERENCES

1. Benedict, Walter H., and Hollenhorst, Robert W.: The influence of cortisone on the rate of blood absorption from the eye, Am. J. Ophth., 36:247-249 (Feb.) 1953.
2. Berens, Conrad: Glaucoma surgery: an evaluation of cycloelectrolysis and cyclodiathermy, A.M.A. Arch. Ophth., 54:548-563 (Oct.) 1955.
3. Castroviejo, Ramon: Cyclodiathermy for the treatment of glaucoma, A.M.A. Arch. Ophth., 53:143-145 (Jan.) 1955.
4. Chandler, Paul A.: Complications after cataract extraction: clinical aspects. In Symposium: Cataract Extraction, Tr. Am. Acad. Ophth., 58:382-396 (May-June) 1954.
5. Chandler, Paul A., and Johnson, Carl C.: A neglected cause of secondary glaucoma in eyes in which the lens is absent or subluxated, Arch. Ophth., 47:740-771 (June) 1947.
6. Davis, Frederick A.: Incision and closure, iridotomy and iridectomy, principles of wound healing. In Symposium: Cataract Extraction, Tr. Am. Acad. Ophth., 58:334-360 (May-June) 1954.
7. Dunnington, John H., and Regan, Ellen F.: Absorbable sutures in cataract surgery, A.M.A. Arch. Ophth., 50:545-556 (Nov.) 1953.
8. Irvine, A. Ray, Jr.: The role of the endothelium in bullous keratopathy, A.M.A. Arch. Ophth., 56:338-351 (Sept.) 1956.
9. Kirby, Daniel B.: Advanced Surgery of Cataract, Philadelphia, J. B. Lippincott Co., 1955, pp. 230-231.
10. Kronfeld, Peter C.: Delayed restoration of the anterior chamber, Am. J. Ophth., 38:453-465 (Oct.) 1954.
11. Kronfeld, Peter C., and Grossman, E. E.: The relation of the gonioscopic findings to the incidence of secondary glaucoma in operative aphakia, Tr. Am. Acad. Ophth., 45:184-196 (May-June) 1941.
12. Lassiter, Lawrence H.: Posterior sclerotomy and air injection in the treatment of flat anterior chambers following cataract extraction, Tr. Am. Acad. Ophth., 60:587-593 (July-Aug.) 1956.
13. Leahey, Brendan D.: Bullous keratitis from vitreous contact, A.M.A. Arch. Ophth., 46:22-32 (July) 1951.
14. McLean, John M.: Gonioscopy in relation to common glaucoma operations, Tr. Am. Acad. Ophth., 45:176-183 (May-June) 1941.
15. ———: Extraction in complicated cases. In Symposium: Cataract Extraction, Tr. Am. Acad. Ophth., 58:371-381 (May-June) 1954.
16. ———: Lens and vitreous, A.M.A. Arch. Ophth., 55:548-564 (April) 1956.
17. ———: Ophthalmological aspects. In Symposium: The Uses and Abuses of the Corticosteroids in Ophthalmology and Otolaryngology, Tr. Am. Acad. Ophth., 60:519-521 (July-Aug.) 1956.
18. Reese, Algernon B.: Herniation of the anterior hyaloid membrane following uncomplicated intracapsular extraction, Am. J. Ophth., 32:933-946 (July) 1949.
19. Roper, Kenneth L.: Suturing in cataract surgery: with a transitional history of cataract; its early treatment; healing of the cataract wound; and the factors that have advanced the development of modern suture technics, Tr. Am. Ophth. Soc., 52:587-749, 1954.
20. Stocker, Frederick W.: Management of endothelial and epithelial corneal dystrophy, Tr. Am. Acad. Ophth., 60:567-575 (July-Aug.) 1956.
21. Thorpe, Harvey E.: Diamox in the treatment of non-leaking flat anterior chamber, Acta XVII Cong. Ophth., 3:1855-1864, 1954.

PART II

POSTOPERATIVE IRIDOCYCLITIS
POSTOPERATIVE INFECTION
AFTERCATARACT

MICHAEL J. HOGAN, M.D.
SAN FRANCISCO, CALIFORNIA

Postoperative Iridocyclitis

A benign inflammation occurs normally in most eyes subjected to uncomplicated cataract surgery. It varies in intensity, but in most patients it subsides without complication, and no special treatment is indicated.

Those patients who have complications during and after cataract surgery develop an iridocyclitis, the severity of which is proportionate to the seriousness of the complication. A number of conditions may lead to iridocyclitis in the postoperative period, and they may be grouped according to the causative factor.

I. *Trauma*

The post-traumatic form of iridocyclitis has been discussed previously. It is due to manipulations incident to the surgery.

II. *Incarceration of Foreign Materials in the Wound*

The surgical procedure may be accompanied by complications which lead to accidental inclusion of intraocular tissue in the wound. Among these tissues are lens cortex, lens capsule, iris, and vitreous. Exogenous materials, such as cilia, ointment bases, and glass from ampuls, may be introduced by the surgeon.

The incarceration of *lens material* in the wound (fig. 1) may occur during extracapsular surgery, or following intracapsular extraction with accidental rupture of the capsule. Lens cortex is softer than lens capsule and is more capable of digestion by tissue enzymes. Often it is gradually absorbed and leads to no serious complications, except for the prolonged inflammation during absorption. At other times it is surrounded by capsule and fibrous tissue (fig. 2).

The presence of lens capsule induces separation of the wound edges. The lens capsule resists digestion, often becoming isolated in the wound by fibrous tissue after a prolonged inflammation (fig. 3). It may act as a wick, and the result may be early or late infection. The inflammation which results from such a complication may be so persistent that surgical intervention becomes necessary. One should suspect such a complication in extracapsular cataract extractions which have a severe persistent postoperative nonsuppurative inflammation.

The incarceration of *iris tissues* in the wound also leads to iridocyclitis (fig. 4). A moderately deep incarceration is of

Francis I. Proctor Foundation for Research in Ophthalmology and Department of Ophthalmology, University of California School of Medicine, San Francisco.

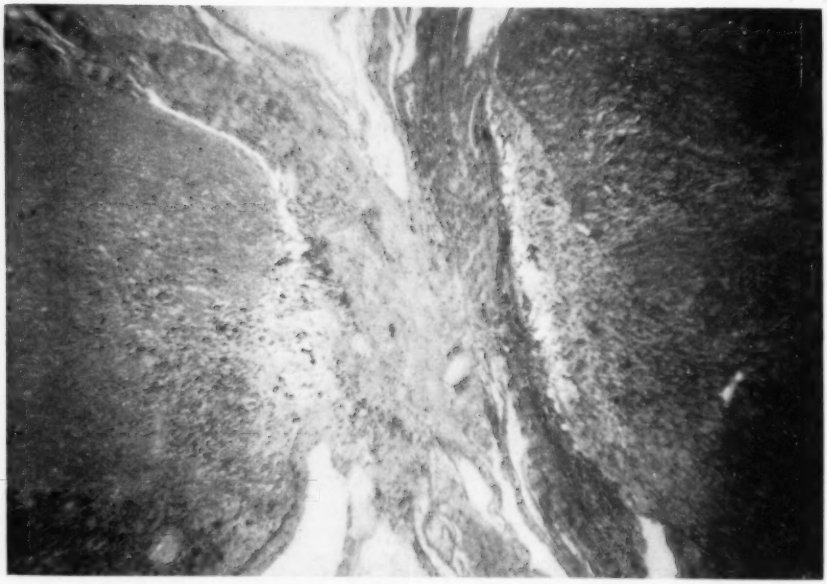


FIG. 1—EP-48-269. Lens-cortex incarceration, postoperative extracapsular extraction.

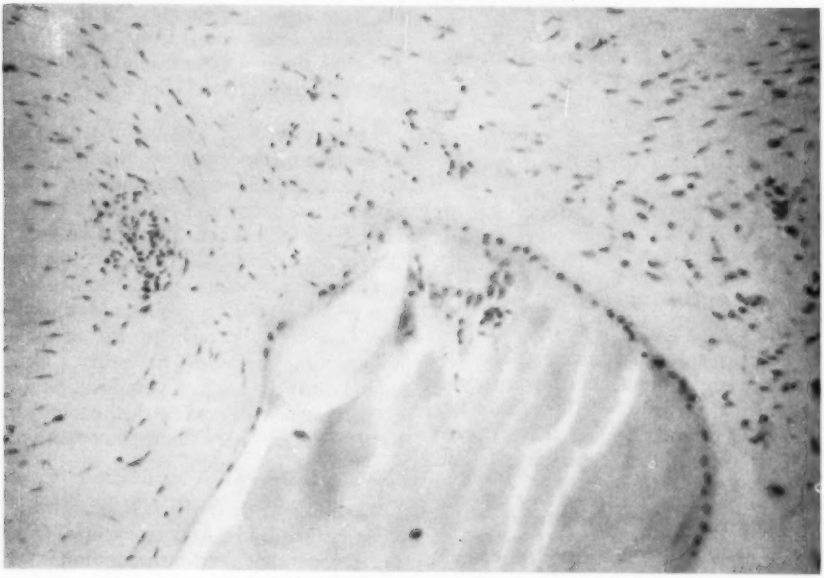


FIG. 2—EP-42-61. Lens incarceration in cataract scar.

FIG. 3—EP-42-61. Lens capsule incarcerated in cataract wound.

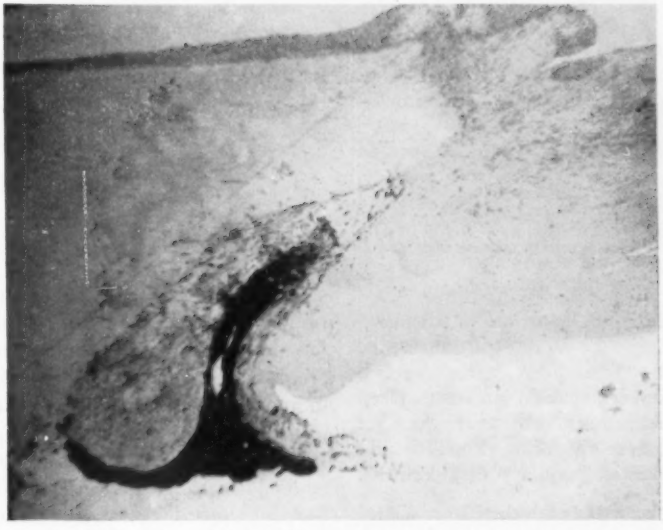


FIG. 4—Iris incarceration following extracapsular cataract extraction.

common occurrence, and its effects are temporary. More marked incarcerations involve greater separation of the wound edges and more prolonged inflammation. Such incarcerations are obvious because of the distortion or displacement of the pupil. In most instances, the inflammation subsides after several months, and sequelae do not ensue. Deep iris incarcerations ordinarily are not treated, unless they are extensive and cause a marked pupillary displacement.

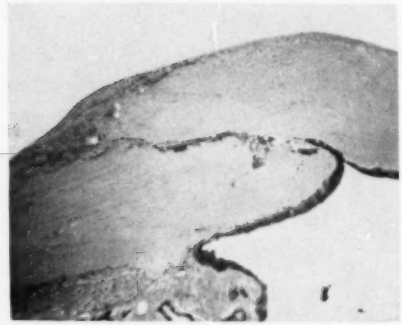


FIG. 5—EP-48-243. Iris prolapse.

Iris prolapse through the corneoscleral wound beneath the conjunctiva is more serious and leads to prolonged inflammation (fig. 5). Those prolapses which are not covered by conjunctiva, if left untreated, may lead to sympathetic ophthalmia. Such prolapses should be excised immediately and should not be treated by medical measures. This complication also will be covered elsewhere in the symposium.

Those prolapses which are covered by a conjunctival flap lead to prolonged inflammation of varying severity. Eventual healing occurs, but with considerable pupillary deformity or an updrawn pupil.

Vitreous may be incarcerated at the time of surgery or later in the postoperative period (fig. 6). Vitreous which becomes adherent to or incarcerated in the wound at the time of surgery may cause prolonged inflammation. The separation of the wound edges results in ingrowth of fibrous tissue. This tissue tends to invade the eye in the form of strands and sheets. Fibrotic tissue extends down along the inner corneal surface for short distances, and strands extend back along the formed portions of

FIG. 6—Vitreous prolapse and incarceration. Note contact of iris and vitreous to cornea and wound.

the vitreous toward the inferior ciliary body. After a period of healing, these bands shrink and may cause retinal separation. Surgical division of the strands of fibrous tissue with scissors or a knife ordinarily is unsuccessful. The wound may be reopened after two or three months, the liquefied vitreous removed, and the strands carefully excised. This procedure is not without danger to the retina, and care must be exercised to avoid traction.

Foreign substances from outside sources, such as cilia, glass from ampuls, and ointment, may produce inflammation of varying severity and duration. If the bulb of the hair is implanted on the iris, it may lead to formation of a pearl cyst, which can be excised. It is best to prevent the entrance of lashes into the wound by trimming them at least twenty-four hours before surgery, and by isolating the lash margin from the operative field at the time of surgery by gutta percha or plastic adhesive drapes.

One should always be cautious about glass at the operating table. Small fragments from epinephrine ampuls may be instilled into the eye with a dropper. Glass often causes recurrent inflammation. Gonioscopy may reveal a small fragment in the angle over the iris surface, removal of which will cure the iridocyclitis.

Ointments may cause a low-grade chronic inflammation, and care should be taken when they are used postoperatively. To prevent this complication, it is preferable to use medicaments in water-soluble bases.

III. *Retained Lens*

Inflammation of the iris and ciliary body occurs in those eyes containing lens cortex after extracapsular cataract extractions. The degree of inflammation depends upon the amount of lens, the rapidity with which it dissolves, and the degree of reactivity of the iris and ciliary body (figs. 7 and 8).

FIG. 7—Postoperative iridocyclitis due to retained lens cortex.

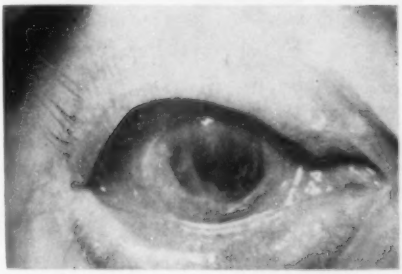


FIG. 8—Postoperative extracapsular extraction. Iridocyclitis due to retained cortex.

Clinical examination reveals the usual signs of iridocyclitis. The small number of keratic precipitates on the cornea are of the round, white, lymphocytic variety; they also may be seen on the iris surface. The iris is edematous and congested, and it reacts poorly to light. The fluffy lens material is easily seen in the pupillary and iridectomy openings.

On histologic examination, the iris shows a nonspecific type of inflammation, with edema, vascular congestion, and heavy infiltration of the stroma and anterior surface with lymphocytes and occasional polymorphonuclear leukocytes (fig. 9). The same cells infiltrate the aqueous, and line the trabeculae and posterior cornea. Varying stages of disintegration are present in the lens itself, with formation of vacuoles con-

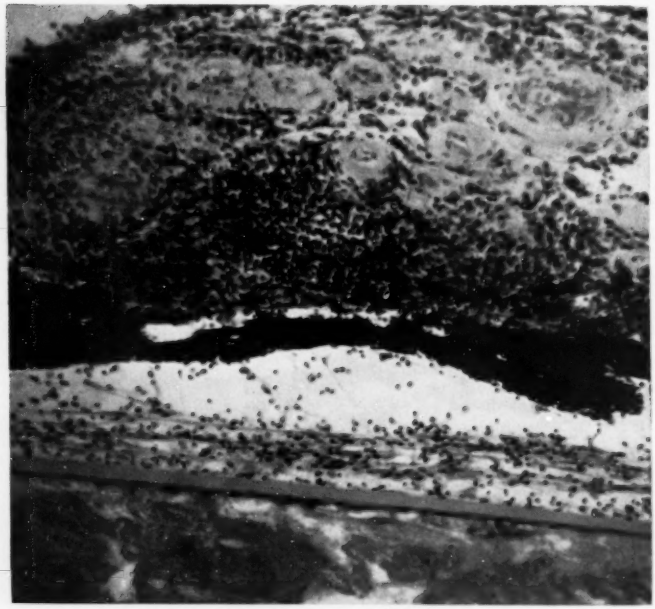


FIG. 9—Toxic lens reaction.

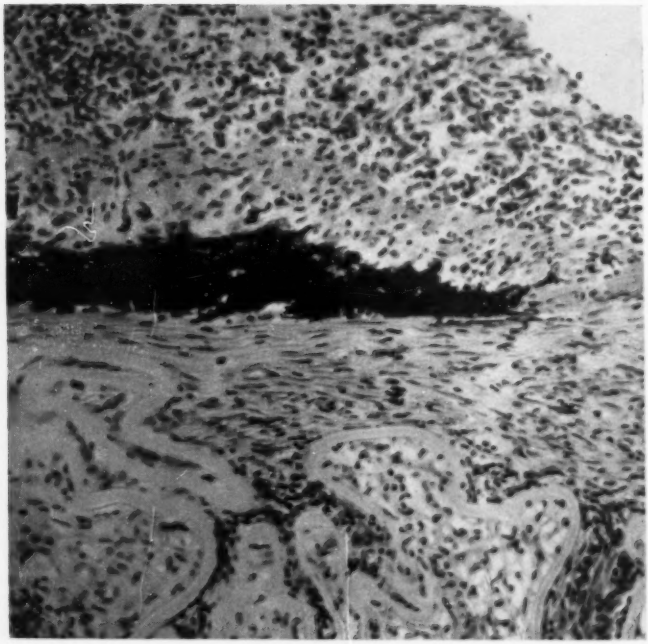


FIG. 10—Scarring due to inflammation caused by toxic effects of lens protein.

taining fluid, solid globules, and fragmentation of the fibers. Chronic inflammatory cells are seen here and there in the dissolving lens substance. The ciliary body presents some inflammation in the processes and stroma, but there is very little involvement of the pars plana, and the amount of exudation into the vitreous is minimal. A nonspecific inflammation, probably induced by the products of the dissolving lens fibers, is the prominent finding. Prolonged inflammation leads to extensive fibrosis (fig. 10).

Treatment of such inflammations depends upon their severity. In the average case, the use of mydriatics and heat assists the absorption of the lens material, and very few complications result. One should avoid the use of topical corticosteroids, because the inhibition of inflammation may lead to slower absorption of the lens material. If the inflammation is severe and convalescence is seriously delayed, the wound may be reopened and the undissolved cortex removed by irrigation.

IV. *Phacoanaphylaxis*

The exact characteristics and causation of this type of inflammation have not been agreed upon by all observers. It has been assumed that the eye can become sensitized to lens protein, and that with sudden liberation of a large amount of this material, an anaphylactic reaction occurs. Clinically, the inflammation is said to resemble that observed in infectious processes in that the exudate is similar (figs. 11 and 12). Some authors state that the prompt cure of such inflammations following removal of the lens is evidence of the anaphylactic nature of the inflammation. However, the exact proof of the local hypersensitivity has not been produced. In supposedly typical cases, the lens substance is infiltrated with polymorphonuclear leukocytes and mononuclear cells (fig. 13),

FIG. 11—Mrs. A. (1946). Phacoanaphylactic endophthalmitis, five days postoperatively. Complete recovery following irrigation. No antibiotics were used.

FIG. 12—Phacoanaphylactic endophthalmitis, two weeks after surgery. Same case as that in figure 11.

and the adjacent iris and ciliary body show some infiltration with polymorphonuclear leukocytes (fig. 14), and lymphocytes. Giant cells containing lens debris are in abundance.

Those eyes developing a postoperative inflammation, suspected of being anaphylactic, in which a purulent type of exudate appears in the pupil and anterior chamber, should have the wound opened and the anterior chamber irrigated. It is gratifying that in many such cases, the inflammation promptly disappears after this treatment. The presence or absence of a low-grade infection in such eyes has not been ruled out with certainty. It is not considered

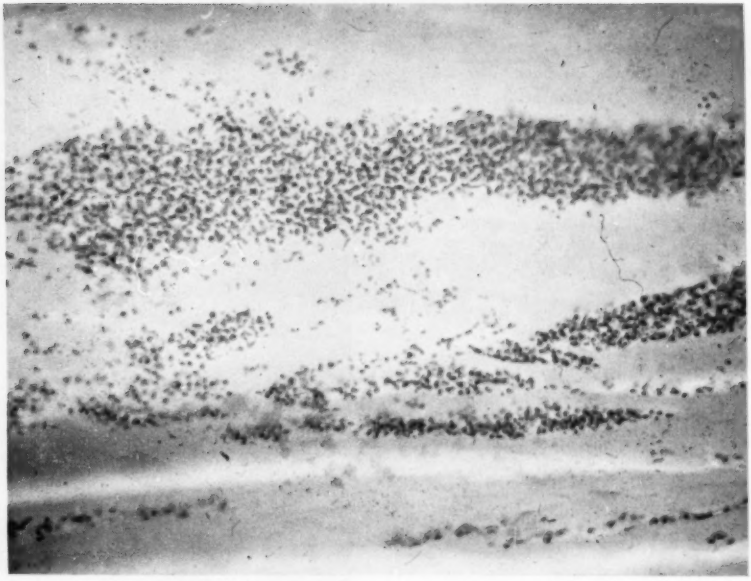


FIG. 13—Phacoanaphylactic inflammation. Note polymorphonuclear leukocytes between lens fibers.

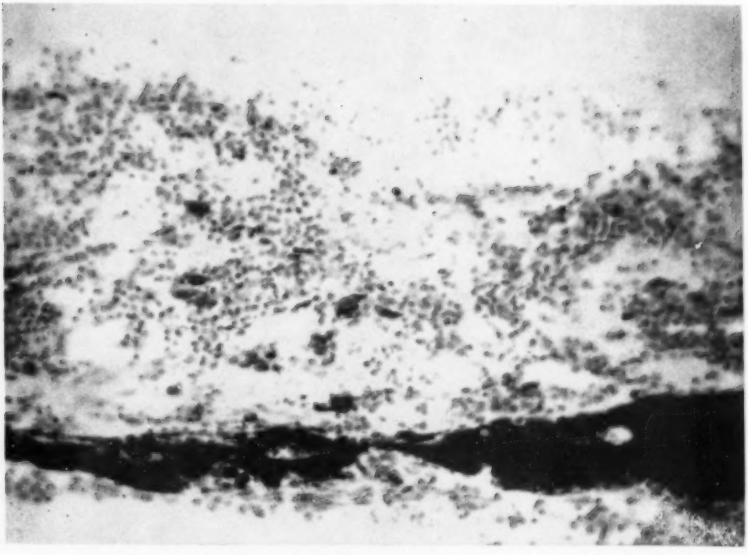


FIG. 14—EP-48-433. Phacoanaphylactic endophthalmitis.

profitable by most observers to perform skin-sensitivity tests or desensitization with lens antigen in those patients who might develop hypersensitivity reactions.

V. *Nonsuppurative Infection*

It is difficult to prove the presence or absence of bacteria of such low virulence that they produce a chronic iridocyclitis. Cases occur, however, in which intracapsular surgery has been accomplished without difficulty, and in which persistent iridocyclitis, turbidity of the aqueous humor, vitreous haze, and discomfort suggest the presence of an infection. Examination in such cases fails to reveal a cause for the inflammation, and one is forced to suspect an infective organism. Such cases may be fostered by the postoperative administration of antibiotics, which prevent the development of frank suppurative inflammation. It seems certain that organisms of low virulence can actually cause a postoperative inflammation. Such infections commence early in the postoperative course. They persist beyond the expected period of iridocyclitis and with greater severity (fig. 15).

Postoperative extracapsular extractions may be more predisposed to this type of infection. In this group of cases it is almost impossible to differentiate between the normal reaction to retained lens, phacoanaphylaxis, and a low-grade secondary infection. Lens material provides an excellent culture medium, and the surgeon always should keep in mind the possibility of such types of infection.

Suspected infection, or an abnormal inflammation in extracapsular extractions, should lead to treatment for infection (see subsequent section) in addition to irrigation of the anterior chamber. This type of infection in intracapsular extraction should lead to vigorous treatment with topical and parenteral antibiotics.

FIG. 15—Probable low-grade postoperative infection, two and a half weeks after intracapsular extraction. Cultures from lids and conjunctiva were negative. Eventual control was attained with chloramphenicol.

SUMMARY

1. Postoperative iridocyclitis after cataract surgery may be due to
   a. Normal reaction to trauma
   b. Incarceration of iris, lens cortex, lens capsule, and vitreous in the wound edges; also, incarceration of cilia, glass or ointments in the wound or anterior chamber
   c. Retention of lens cortex
   d. Phacoanaphylaxis
   e. Nonsuppurative infection
2. Incarceration of lens cortex or a small amount of iris may cause little inflammation. Incarceration of lens capsule and prolapse of iris or vitreous may lead to prolonged and severe inflammation with serious visual results.
3. Persistent inflammation is an indication that the wound should be explored if a cause for the inflammation has not been found.
4. The inflammation due to anaphylaxis and retained lens can be eradicated by irrigation of the anterior chamber.
5. The diagnosis of nonsuppurative infection may be difficult, but persistent inflammation in the absence of a specific cause should suggest this complication.

Postoperative Infection

The frequency of postoperative infection surprisingly has changed very little during the period following the introduction of chemotherapeutic and antibiotic agents. Recent studies, however, indicate the reasons for the failure of reduction in the incidence of infections, and demonstrate methods whereby it can be reduced. The frequency of postoperative infection has varied from 0.5 per cent to 2 per cent in the various series reported in the last twenty years. Pathogenic Staphylococcus aureus leads other organisms in the frequency with which it causes infection, followed by Streptococcus, Pneumococcus, and Gram-negative organisms (coliform bacteria, Pseudomonas).

Postoperative infections may be classified according to time as (a) early and (b) late; according to source as (a) endogenous and (b) exogenous; and according to type as (a) suppurative (localized or diffuse) and (b) nonsuppurative (previously discussed).

A discussion of surgical infections must include a description of the methods employed to prevent such infections.

PROPHYLAXIS

The Preoperative Prevention of Infection

A. The patient

1. Such systemic diseases as diabetes should be searched for and controlled. Remote foci of infection should be treated if they might contribute to failure of the surgical result.

2. Careful clinical observation of the local state of the lids, conjunctiva and lacrimal apparatus should be made. The occurrence of epiphora should be sought in the history. The presence of a seborrheic blepharitis with negative cultures is not a contraindication to surgery. If there is any inflammation, cultures should be made from the *lid margins*. The flora of the lid margins determines the flora of the conjunctival sac, so it is more important to take cultures at this site.

Institutions and eye departments having adequate facilities should take routine preoperative cultures. Ophthalmologists with less well organized facilities should rely on careful examination of the external ocular structures for evidence of infection.

Cultures may be taken from the lid margins from two to seven days prior to surgery, and the material should be placed on blood agar as well as on mannitol-agar plates with an indicator. Organisms of significance include (a) Pneumococcus, (b) Streptococcus, (c) Proteus, (d) Pseudomonas, (e) any Gram-negative rod, and (f) any coagulase-positive or mannitol-positive Staphylococcus or hemolytic Staphylococcus aureus. The coagulase test is the better of the two to detect pathogenic staphylococci.

Locatcher-Khorazo and Gutierrez[1] have found that the incidence of Staphylococcus aureus in routine preoperative cultures has been increasing during the past fifteen years; for example, from 1938 to 1945, 21 per cent of cultures were positive, whereas during the fall of 1954, 68 per cent were positive. Also, the resistance of the organism to penicillin is increasing. From 1945 to 1950, 86 per cent of strains of Staphylococcus aureus were sensitive to penicillin, whereas from 1951 to 1954, only 22 per cent were sensitive. A similar reduction in sensitivity of Staphylococcus aureus to terramycin, chloramphenicol, and streptomycin was also observed.

McNeill[3] found 48 per cent of staphyl-

ococci from 175 patients with chronic external ocular infections were resistant to penicillin.

If cultures are positive, adequate therapy must be taken with chemotherapeutic or antibiotic agents to eradicate the organisms.

B. Topical prophylaxis

Prophylactic agents should be applied to the lid margins and not to the conjunctival sac, because the lid infections lead to secondary conjunctival involvement. It is better to apply ointments in the preoperative period, because solutions do not sterilize the lids. Either a sulfonamide or Polysporin® or Neosporin® ointment may be used two to three times daily. In other cases it might be more desirable to use a broad-spectrum antibiotic ointment. Prophylaxis is carried out for at least a week prior to surgery.

C. Systemic prophylaxis

Many surgeons are opposed to preoperative systemic prophylaxis on the basis that the antibiotics used frequently are not active against the commonest organism causing postoperative infection (Staphylococcus aureus), or that they are ineffective against some of the Gram-negative organisms encountered (Proteus, Pseudomonas). They also object on the basis of the frequency of systemic sensitivity (especially to penicillin). The risk in the systemic use of a sulfonamide or antibiotic is definite, although the use of Mycostatin® with the broad-spectrum antibiotics reduces the frequency of gastrointestinal effects. Approximately 50 to 70 per cent of hospital strains and at least 30 per cent of nonhospital strains of pathogenic staphylococci are resistant to penicillin. Therefore, the use of this antibiotic for systemic prophylaxis is to be questioned, especially in view of its ability to cause sensitivity reactions. The employment of combinations of penicillin and streptomycin is common, and it must be admitted that these combinations have some effect in the prevention of infection. However, other methods seem more logical. This point will be discussed later. It is our opinion that systemic prophylaxis should be avoided.

The Operative Prevention of Infection

Meticulous care should be observed in the operating room. The surgeon should wear gloves unless he carries out his surgery by the methods advocated in some clinics in Europe, where instruments are constantly changed and where the same instrument is never used a second time until it has been sterilized. In the European method, the hands should never touch the portion of the instrument to be inserted into the eye, nor should suture materials be touched by the hands. This method would be considered almost impossible in this country, especially where cataract surgery has become involved and time consuming. With increasing time consumed in the surgical procedure, there is additional trauma, and therefore added risk of infection. For these reasons it seems to us that gloves are essential in the performance of intraocular surgery.

Maumenee[2] has shown that it is impossible to eradicate all bacteria from the skin of the lids by the usual scrubbing techniques. He found that scrubbing with Phisoderm® containing 3 per cent hexachlorophene, followed by painting with iodine 3.5 per cent, or 1:1000 tincture of Zephiran®, gave the highest incidence of negative cultures following a 3-minute scrub. Because of the inability to sterilize the skin of the lids, Maumenee felt that following the proper scrub and application of the antiseptic, the lid-margin area should be isolated from the operative field by gutta-percha drapes. We have found plastic drapes with adhesive edges to be equally effective.

Instruments should not be sterilized by boiling or by cold sterilizing agents unless this is absolutely unavoidable. All nonsharp instruments should be sterilized in the autoclave, and sharp instruments should be individually packaged and sterilized with dry air.

All medications used prior to and during surgery should be sterile. Individual packages are available for such medications.

The Postoperative Prevention of Infection

A. Topical prophylaxis at the termination of surgery.

Pearlman[4] recently published the results of administration of subconjunctival penicillin plus streptomycin at the termination of cataract surgery. Of 3,226 patients receiving this prophylaxis, none had postoperative infections. This should be compared with four infections (due to Gram-negative organisms) in 1,202 other patients, and nine infections in 1,773 patients not receiving prophylaxis at the end of surgery. Such figures are convincing, and provide another reason for avoiding systemic prophylaxis with these antibiotics. We have been accustomed to instillation of Neosporin® ointment in the conjunctival sac at the termination of surgery, and since instituting this method (1955), we have not observed a postoperative infection in approximately five hundred patients subjected to intraocular surgery.

Dressings should be changed daily on patients who have undergone cataract surgery. The dressing should *always* be changed on the first postoperative day, and it is wise to establish the habit of examining the aphakic eye with the ophthalmoscope. One of the earliest signs of an infection is a turbidity of the media, which often cannot be detected with a flashlight (fig. 16). If there is no evidence of infection, an antibiotic ointment (preferably Neosporin® or Polysporin®) should be instilled.

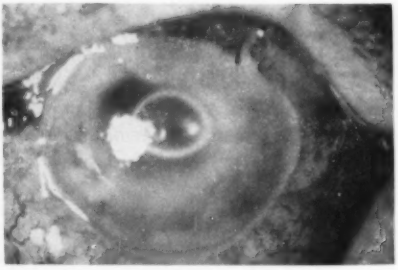


FIG. 16—Endophthalmitis, six days after cataract extraction.

TREATMENT

Treatment of Postoperative Infections

If the eye becomes infected, most commonly about the second or third day, the dressings should be left off, except for a protective shield, and the following measures should be undertaken:

A. *Cultures.* Material should be taken from the *lid margin* as well as from the conjunctival sac and from the region of the conjunctival flap (if present) provided exudate is present at that site (fig. 17). The material should be placed in broth, and on blood agar plates. For medicolegal reasons also, it is important to make an attempt to recover an organism.

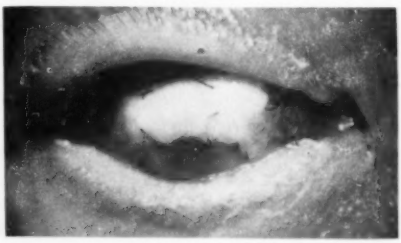


FIG. 17—Infection by a Gram-negative rod following an intracapsular cataract extraction. The eye was lost.

B. *Immediate therapy.* One should first suspect an infection with a pathogenic Staphylococcus aureus or one of the Gram-negative organisms. (If the

infection should be due to a streptococcus or a pneumococcus, it would respond to most of the usual forms of therapy.) In view of the resistance of staphylococci to penicillin and to some broad-spectrum antibiotics, it is wise to give the following drugs systemically: (1) sulfadiazine—an adult dose of 3 to 4 grams a day by mouth; (2) an antibiotic such as Chloromycetin®, Achromycin®, or erythromycin in a dosage of 2 to 3 grams a day.

In addition to systemic therapy the following topical measures should be instituted:

1. Neosporin® ointment instilled into the conjunctival sac at least every two hours.

2. A penicillin-streptomycin mixture, as advocated by Pearlman,[4] injected subconjunctivally every twenty-four or forty-eight hours.

In rapidly progressive cases, one should consider the injection of penicillin into the anterior chamber or vitreous in a dosage of 5,000 units. As soon as the results of culture are learned, one should alter the treatment as indicated. If a Gram-negative organism is present, the sulfadiazine may be discontinued and streptomycin given intramuscularly in a dosage of one gram twice daily. If a pathogenic Staphylococcus aureus is recovered and if the infection has not shown a tendency to subside, sensitivity tests should be carried out (fig. 18). Tube sensitivity tests are considered to be more accurate, but disc sensitivity tests provide qualitative evidence, which is sufficiently satisfactory. If an antibiotic shows activity against the organism, it should be administered in full dosage.

If these measures fail, and if the anterior chamber is not clearing and the infection does not seem to involve the posterior ocular tissue, it is advisable to remove the sutures, open the wound, and irrigate the anterior chamber. Upon closing the wound, it is best to leave an antibiotic solution in the chamber, such as Neosporin® solution, or Chloromycetin.®

FIG. 18—Staphylococcic infection following intracapsular cataract extraction. This infection was resistant to all antibiotics and resulted in eventual enucleation.

Occasional infections with Pseudomonas, if detected early, might provide an indication for systemic therapy with polymyxin, but this should not be undertaken without full advice of a medical consultant.

The increasing incidence of resistant staphylococci in nonhospital and hospital patients should make the surgeon constantly aware of the problems involved in the treatment of infections due to this organism. The newer antibiotics which are active against staphylococci should be used sparingly and reserved for such cases.

Late Infections

Some patients treated with antibiotics prior to and following surgery may have an infection which smoulders during the course of therapy and becomes active when it is discontinued. Such infections usually develop in the later postoperative period and may or may not be suppurative, depending on the causative organism. Realization of the nature of the inflammation and prompt institution of therapy usually results in a cure.

Late (endogenous) infection from a remote focus in the body at the fifth day,

or later, after surgery is of rare occurrence during the present era, possibly because of the better general physical condition and care of those patients subjected to surgery.

Pathologic Considerations

At first the infection may be restricted to the wound area. Within a short time it spreads to the adjacent iris. If it is restrained to the anterior segment, the exudate fills the chamber, creating the picture known as *suppurative iridocyclitis* (fig. 19). Under such circumstances, it might be possible to evacuate the chamber and to overcome the infection with antibiotics. Most frequently, however, the infection is not restrained and extends to the posterior segment, causing an endophthalmitis or panophthalmitis (fig. 20). Systemic therapy, or intravitreal injections of antibiotics, would be the only local method of treatment in such cases.

FIG. 19—EP-48-269. Infection following cataract extraction.

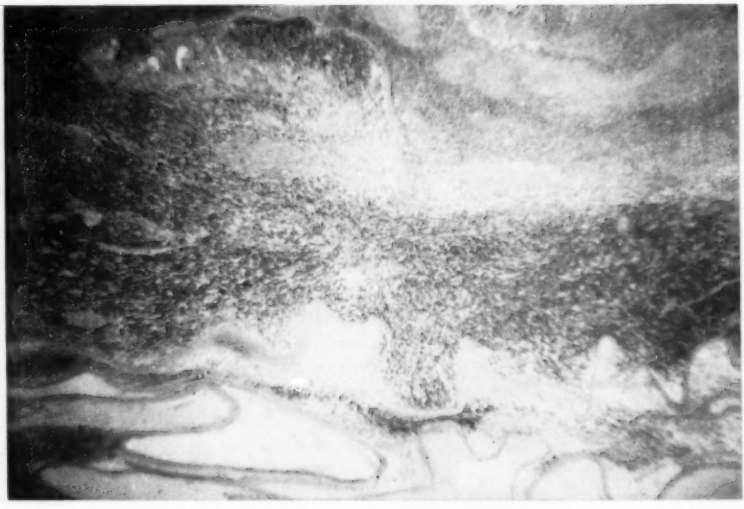


FIG. 20—EP-47-81. Infection following extracapsular cataract extraction.

SUMMARY

1. Preoperative prevention of infection may be summarized as follows:
   a. Detection of systemic diseases and eradication of foci of infection.
   b. Careful clinical study of the lids, conjunctiva, and lacrimal apparatus to detect an infection. Tissues for culture should be taken from the

lid margins in suspected cases, and all pathogens should be eradicated prior to surgery.

c. Topical prophylaxis against infection with a sulfonamide or Neosporin® or Polysporin® ointment should be used for a week prior to surgery.

d. Systemic prophylaxis should be avoided.

2. Neosporin® or Polysporin® ointment should be used at the end of surgery, or a subconjunctival injection of penicillin-streptomycin should be given.

3. Infections should be treated energetically from the onset with sulfadiazine and Chloromycetin®, Achromycin®, or erythromycin in adequate dosage by mouth. Topical therapy with Neosporin® ointment should be given, and a penicillin-streptomycin injection should be given subconjunctivally every two days until the nature of the infection is known.

4. If the infection is due to a Gram-negative coliform organism, the sulfadiazine should be discontinued and intramuscular streptomycin substituted.

5. Pseudomonas infection may be treated with polymyxin parenterally and topically, but only with the advice of an internist.

Aftercataract

A membrane of varying composition and consistency may remain in the pupil after the extracapsular extraction of cataract. The composition and consistency of the membrane varies according to the following conditions:

1. The extent to which the anterior capsule and epithelium are removed at the extracapsular extraction

2. The degree of iridocyclitis following surgery

3. The size of the pupil and presence of synechias

4. The presence or absence of hemorrhage in the postoperative period

The usual aftercataract is composed of the thin posterior capsule, covered by a fine layer of hyaline-like material (fig. 21). This membrane may be smooth or crinkled, depending on adjacent iris adhesions or tension on zonular fibers. It is transparent and does not interfere particularly with vision (fig. 22).

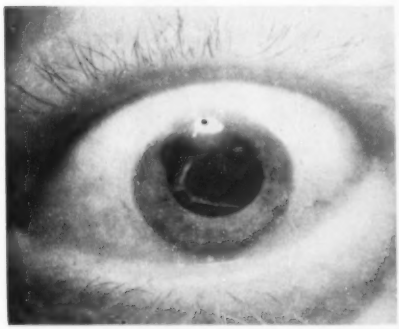


FIG. 21—Postoperative extracapsular pupillary membrane.

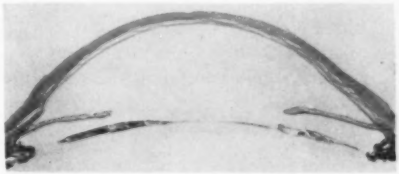


FIG. 22—EP-45-28. Sommering ring. Pupillary membrane.

Delay in closure of the anterior-posterior capsule margins, or incomplete removal of the anterior capsule, may lead to proliferation and swelling of the anterior epithelial cells to form abortive lens fibers. These extend across the pupil, where they are observed as masses

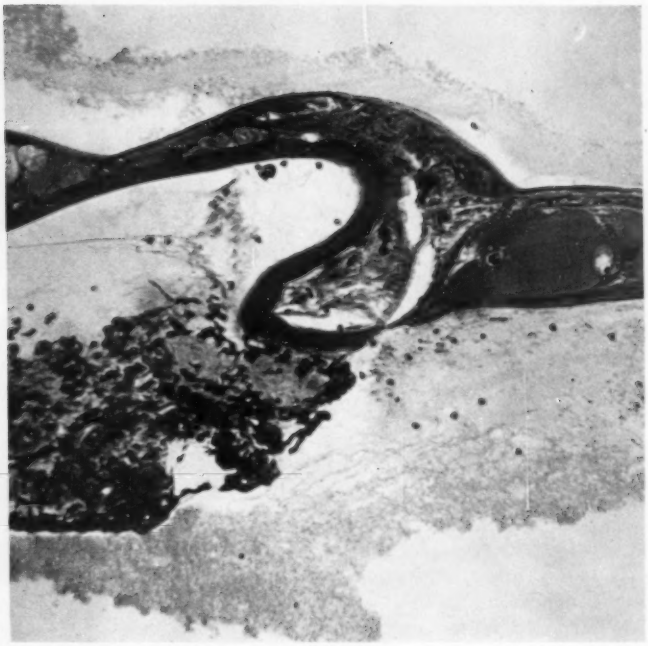


FIG. 23—Postoperative pupillary membrane. Proliferation of lens epithelium to form Elschnig pearls.

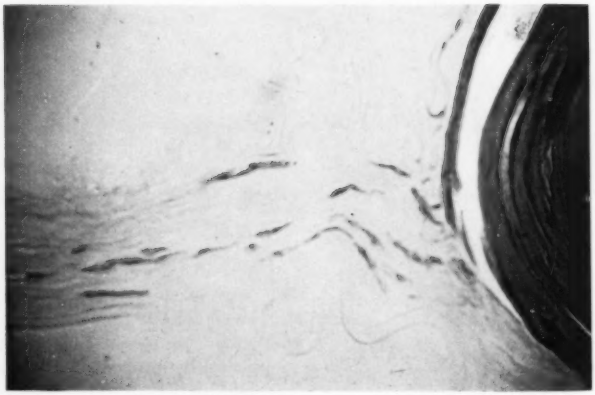


FIG. 24—Fibrous postoperative pupillary membrane resulting from extracapsular extraction.

(Elschnig pearls) (fig. 23). When proliferated to form clusters, they interfere decidedly with visual acuity.

Chronic iridocyclitis after surgery, whatever its cause, often leads to exudation, deposition of fibrin on the lens capsule, synechia formation, proliferation of fibroblasts from the iris stroma onto the capsule, and eventual organization into a fibrous membrane (fig. 24).

Hemorrhages, especially those which are recurrent, often lead to the formation of clots in the pupillary region, which organize and form fibrous masses (fig. 25).

Some patients who have undergone successful intracapsular cataract surgery, also, may develop an acute iridocyclitis and organization of a membrane on the face of the vitreous, especially if the pupil cannot be kept dilated.

One can often predict the type of membrane which will form, depending on the postoperative course. In uncomplicated cases, the membrane may be a thin posterior capsule in the pupillary region. Those patients with prolonged inflammation or hemorrhages exhibit fibrous membranes. In some cases, there are masses of Elschnig pearls.

TREATMENT

The general principles of surgery for pupillary membranes may be listed as follows:

1. Care should be exercised to prevent infection.
2. Traction on the pupillary membrane during its severance should be avoided.
3. The knife should not pass deeply into the vitreous.
4. Care should be taken to avoid the withdrawal of vitreous with the knife into the discission wound.
5. The incision should be made at right angles to the traction lines in the membrane as observed with the slit lamp microscope.

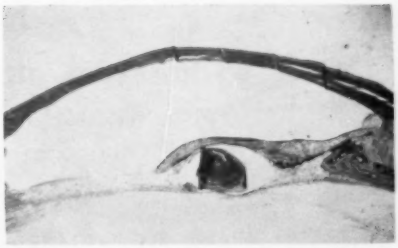


FIG. 25—EP-48-100. Lens capsule in wound following extracapsular cataract extraction. Fibrous ingrowth. Pupillary membrane.

It is not the purpose of this discussion to go into the details of surgical techniques utilized for the treatment of pupillary membranes of various types, because they are adequately described in standard texts.

Management of Thin Membranes

Thin membranes, with or without Elschnig pearls, are best treated by discission with the Ziegler knife (fig. 26).

FIG. 26—EP-41-30. Ziegler discission opening.

The knife should be sharp (as tested on a drum) and should be as small as possible. Excellent light and good magnification are essential. Fixation is obtained opposite the prolapsed point of entry of the knife, and the knife enters the cornea near the limbus. The tip of the knife picks up the membrane and gently teases it apart at a number of points, with very little traction. Within a short time a satisfactory opening is obtained.

Management of Dense Membranes

Dense membranes containing some fibrous tissues, but not sufficiently thick to obscure the fundus reflex, should be incised with the Wheeler knife (fig. 27).

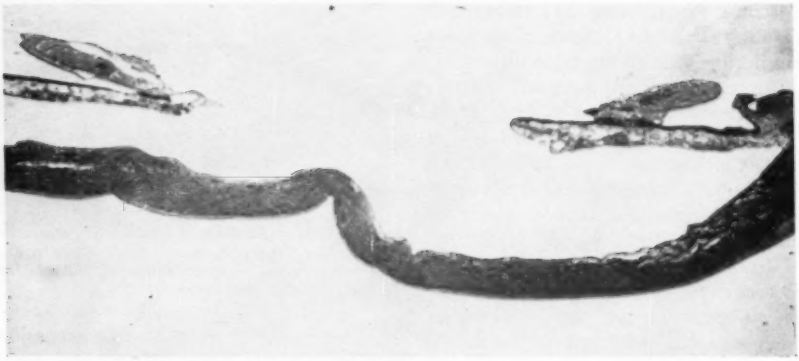


FIG. 27—EP-44-30. Discission of pupillary membrane resulting from extracapsular cataract extraction.

The knife should be sharp, and of the smallest size. It should be inserted into the cornea close to the limbus, and the membrane should be incised at the selected point, with the tip of the knife kept close to the membrane itself. Careful watch should be made during the incision to see that too much traction is not being made.

Management of Fibrous Membranes

Dense fibrous membranes are best treated by incision with the Berens or De Wecker scissors. Wherever necessary, a triangular flap may have to be removed. It goes without saying that vitreous is lost during the procedure, and the surgeon should be prepared to take great pains to prevent adhesions to the wound. He should avoid making traction on the membrane during surgery. If it can be incised without grasping it with a forceps, the chance of retinal complication is lessened.

SUMMARY

1. Aftercataract may be composed of (a) a thin and transparent posterior capsule, (b) a posterior capsule plus proliferating lens epithelial cells (Elschnig pearls), or (c) a capsule plus fibrous tissue derived from iris tissue in iridocyclitis or from organizing exudate as the result of previous hemorrhage.
2. If surgical therapy becomes necessary, the incision should be made with a Ziegler knife for thin membranes, with a Wheeler knife for slightly fibrous membranes, and with a Berens or De Wecker scissors for dense fibrous membranes.
3. Care should be taken to avoid traction in incising such membranes, also to prevent deep penetration of discission knives into the vitreous.

I wish to acknowledge the advice given by Drs. Phillips Thygeson and Samuel J. Kimura in preparation of the section on postoperative infection.

REFERENCES

1. Locatcher-Khorazo, Deborah, and Gutierrez, Elizabeth: Eye infections following cataract extraction, with special reference to the role of Staphylococcus aureus, Am. J. Ophth., 41:981-987 (June) 1956.
2. Maumenee, A. Edward, and Michler, Raymond C.: Sterility of the operative field after ocular surgery, Tr. Pacific Coast Oto-Ophth. Soc., 32:172-183, 1951.
3. McNeill, John Alexander: Bacterial sensitivity tests in treatment of chronic external ocular infections, Am. J. Ophth., 36:480-488 (April) 1953.
4. Pearlman, Maurice D.: Prophylactic subconjunctival penicillin and streptomycin after cataract extraction, A.M.A. Arch. Ophth., 55:516-518 (April) 1956.

PART III

EPITHELIAL INVASION OF THE ANTERIOR CHAMBER
RETINAL DETACHMENT
CORNEAL EDEMA
ANTERIOR CHAMBER HEMORRHAGES
CHANGES IN THE MACULA

A. EDWARD MAUMENEE, M.D.
BALTIMORE, MARYLAND

Epithelial Invasion of the Anterior Chamber

EPITHELIAL invasion of the anterior chamber following cataract extraction should be classified under the headings of epithelial pearls, epithelial cysts, and epithelial downgrowths.[20] The first of these occurs after the implantation of a hair follicle or a piece of skin into the anterior chamber. Clinically, such lesions appear as isolated pearls or pearl cysts on the surface of the iris, not necessarily connected with the wound of entry into the anterior chamber. Implantations of epithelium of this type are so rare after cataract surgery that they do not warrant further discussion at this time.

The incidence of epithelial cyst formation or epithelial downgrowth into the anterior chamber after cataract extraction is difficult to ascertain. Most of the reports on these conditions have been based on histologic studies of enucleated eyes and not on the clinical occurrence of the lesions. Thus, Theobald and Haas[25] reported an incidence of 0.11 per cent of histologically proved epithelial invasion of the anterior chamber in 8,062 cataract extractions. A clearer picture of the importance of epithelial invasion is obtained by noting the incidence of the lesion in eyes requiring enucleation after cataract extraction. Thus, in five studies listed in table I,[1,13,19,20,25] epithelial invasion was found in 170 of 1,186 eyes that required enucleation. This is an incidence of 14.3 per cent, or about one in every seven eyes removed.

Histologically it is difficult to distinguish an epithelial cyst from an epithelial downgrowth; however, the clinical picture and the course of these conditions differ markedly.[14]

Epithelial cysts of the anterior chamber are usually easy to diagnose. They appear, characteristically, as translucent or grayish cysts which are connected, at least at one point, with the corneal wound or area of perforation into the anterior chamber (fig. 1). Occasionally, a cyst may invade the posterior chamber through a peripheral iridotomy, or it may actually erode the iris. If this occurs, the iris overlying the cyst becomes thinned, and the cyst appears to arise from the iris stroma. On other occasions, when the epithelium invades the posterior chamber, a light sprinkling of pig-

From the Wilmer Ophthalmological Institute, The Johns Hopkins University and Hospital, Baltimore.

ment may cover its surface. Few conditions closely simulate epithelial cysts of the anterior chamber.

The rate of progress of these cysts is extremely variable. An epithelial cyst may lie dormant for years before it makes its appearance in the anterior chamber, or it may grow to considerable size and then remain stationary, without causing further damage to the eye. Some cysts cause chronic iridocyclitis; while others may be large enough to produce an intractable secondary glaucoma, necessitating enucleation.

neal involvement. In such regions there is a slight loss of normal iris markings and of iris mobility. Careful examination with the biomicroscope, under high magnification, may reveal a thin film on the anterior surface of the iris. In other instances, the iris may be drawn up toward the incision made for the cataract extraction. If a total iridectomy has been done, there may be a condensation on the face of the vitreous in the area involved. A low-grade iridocyclitis may or may not accompany the process.

The epithelium grows more rapidly

TABLE I

EYES ENUCLEATED AFTER CATARACT EXTRACTION

INSTITUTION	NO. EYES REMOVED	NO. WITH EPITHELIZATION	PERCENTAGE	DATES
Institute of Ophthalmology, Presbyterian Hospital, New York[20]	35	4	11	1929-38
Illinois Eye & Ear Infimary[25]	75	14	18	1934-45
University of Iowa[1]	145	30	20	
Stanford University[13]	42	9	21	1949-55
Armed Forces Institute of Pathology[19]	889	113	12	1944-53
Total	1,186	170	14.3	

*For source of cases see references 20, 25, 1, 13 and 19.

Epithelial downgrowths, or epithelization of the anterior chamber, on the other hand, are frequently difficult to diagnose clinically. Calhoun[2] has given an excellent description of the clinical picture and course of these lesions. In relatively undeformed postoperative eyes a thin translucent membrane, with a fine gray line at its lower border, can be detected on the posterior surface of the cornea when the eye is carefully examined with a slit lamp and biomicroscope (fig. 2). The overlying cornea is frequently slightly edematous, and newly formed vessels may or may not be present in the deeper layers of the stroma. Epithelium also may cover the surface of the iris underlying the area of corover the surface of the iris and trabecula than it does on the back of the cornea; therefore, the progress of corneal involvement cannot be used as a criterion of arrest or retardation of epithelial invasion. If the lesion progresses over a long period of time, an intractable secondary glaucoma usually develops from occlusion of the trabeculae by newly formed epithelium or by iridocyclitis. In eyes that have been markedly deformed by cataract extraction, persistent corneal edema, iris distortion, vitreous adhesions to the cornea, retained lens material, iris adhesions to the posterior surface of the cornea, and chronic nonspecific iridocyclitis may obscure the picture.

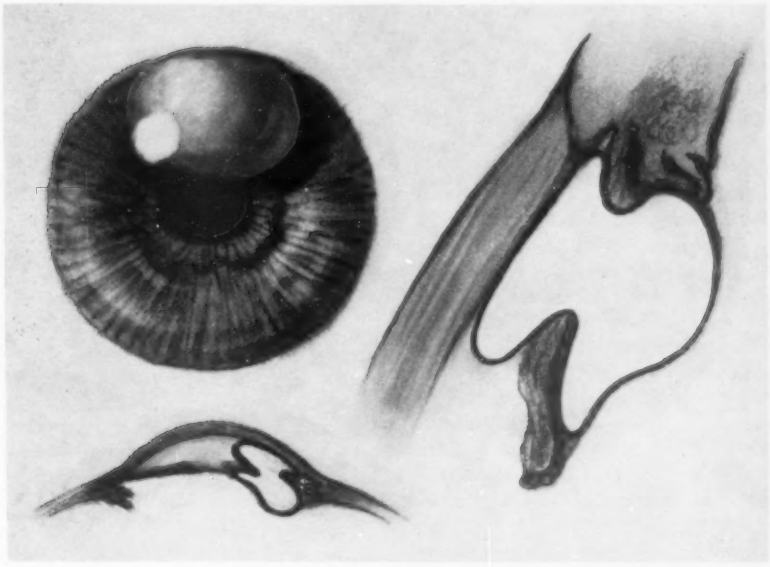


FIG. 1—Epithelial cyst of anterior chamber.

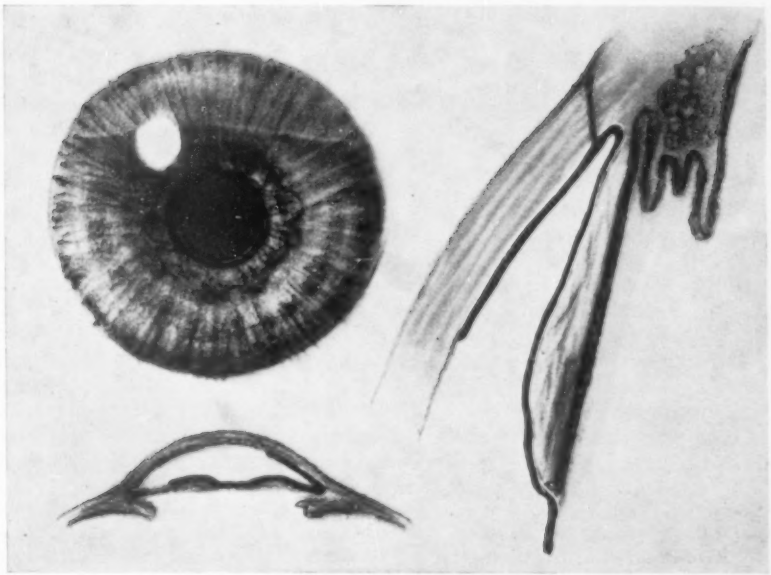


FIG. 2—Epithelial downgrowth.

A number of lesions may closely simulate epithelial downgrowth. Some of these are (1) a very shelving corneal section for cataract extraction, (2) vitreous in contact with the posterior surface of the cornea following a wide iridectomy for cataract extraction, (3) invasion of the anterior chamber by connective tissue and blood vessels, (4) a peeling off of Descemet's membrane on the posterior surface of the cornea above, and (5) a glassy membrane on the posterior surface of the cornea and anterior surface of the iris. This last-mentioned condition is the most difficult lesion to differentiate from epithelization of the anterior chamber. These glassy membranes usually occur in eyes which have undergone a prolonged iridocyclitis. The membrane consists of a newly formed Descemet's membrane on the posterior surface of the cornea and an extension of the same tissue from above over the anterior surface of the iris. In all of the other conditions, the anterior surface of the iris either is not involved or is involved only slightly in the process. In detachment of Descemet's membrane, it may be observed curling inward at its inferior edge. This should not be confused with the gray line due to a piling up of epithelioid cells at the lower edge of the downgrowth.

Delayed closure of the wound is the most frequent cause of both epithelial cyst formation and epithelial downgrowth in the anterior chamber. This may result from poor surgical coaptation of the wound edges or inclusion of lens capsule, vitreous, iris, conjunctiva or other foreign material in the wound. Occasionally, corneoscleral sutures which have been placed too deep in the tissue and near the anterior chamber appear to be implicated in epithelial invasion of the anterior chamber. This is not a condemnation of corneoscleral or cornea-to-cornea sutures, however, for when properly placed in the superficial one third, or less, of the tissue, they give the best possible closure of the wound and, therefore, the best protection against epithelial invasion. An adequate limbal-based conjunctival flap, at least 2 mm. wide in all areas of the corneal section and not buttonholed, appears to offer some protection from epithelial invasion.

Why an epithelial cyst occurs in one case and an epithelial downgrowth in another is not known.

Numerous forms of treatment have been suggested for epithelial cysts.[14] Among these are repeated tappings of the cyst, coagulation with electrodiathermy or electrolysis either before or after the cyst has been evacuated, irrigation of the cyst with various corrosive solutions, irrigation with radioactive isotopes, irradiation of the cyst, and partial excision or attempted complete removal of the cyst. Each of these forms of treatment has its advocates, and occasionally successful results have been reported with each type of treatment.

Our choice of treatment of this condition is as follows: If the cyst is small, 2 to 3 mm. in diameter, is not growing, and is not causing an iridocyclitis, photographs may be taken of the cyst and the eye observed. Periodic gonioscopic examinations of the angle in the area of the cyst should be done to note its extension along the trabecula. However, if the cyst is growing, causing an iridocyclitis, occupying one fourth of the anterior chamber, or invading the posterior chamber, then surgical treatment is indicated. In the cases of small cysts, 2 to 4 mm. in diameter, that collapse completely when aspirated, the technique of treatment advocated by Hogan[9] may be used. This involves inserting a hypodermic needle, insulated to its tip, into the cyst, evacuating the cyst, and then applying diathermy to the base of the needle. If the lesion is large, however,

and does not collapse after aspiration, then surgical removal is suggested. An incision is made into the anterior chamber through the sclera at the base of the cyst. This opening should be of sufficient size to allow 2 to 3 mm. of the periphery of the cornea to be curetted free of epithelium. The iris then is removed in the area where the epithelium is adherent. The chances of eliminating the cyst and preserving the eye after such treatment are excellent; that is, if the cyst is not too large (fills not more than one half of the anterior chamber) or is not complicated by secondary glaucoma or persistent corneal edema.

The suggested treatment of epithelization or epithelial downgrowth of the anterior chamber is not such a simple matter. In the past, many workers have felt that eyes so involved were hopelessly lost. The most frequently advocated therapy has been irradiation to the anterior segment of the globe. However, the results of such therapy have been equivocal for the following reasons: (1) Even in the most favorable series, only 50 per cent success has been recorded. (2) The diagnosis of epithelial downgrowth has not been established by biopsy prior to treatment, so it is entirely possible that many of the cases which were presumed to be successfully treated were cases of lesions other than epithelial downgrowth. (3) Reported cures have resulted from as little as 300 r in some instances, and failures to destroy the epithelial membrane or stop its progress have been cited with as much as 2,400 r. (4) Finally, the treated patients frequently have been followed for less than a year after treatment, a period insufficient to evaluate the treatment used.

I have examined two eyes histologically that have received 1,100 r and 2,700 r, respectively, for epithelial downgrowth. In both eyes an epithelial membrane was still present. In the first instance the eye was removed three months after roentgen therapy, and in the second, eleven months after treatment.

It has been suggested that operation on an eye with an epithelial downgrowth may produce an exacerbation of the lesion and, therefore, is contraindicated. The following case history, however, suggests that this is not always true. On October 22, 1953, a patient was observed with an epithelial downgrowth that covered the upper fourth of the cornea and one third of the iris. He had had a round-pupil intracapsular cataract extraction on August 11, 1953. On October 28, 1953, the old cataract wound was opened almost to its full extent. The cornea was turned back, and the epithelium was loosened by rubbing the posterior surface of the cornea with a cotton swab which had been dipped in 70 per cent alcohol and then wrung relatively dry. The epithelium then was removed with a curet. A basal iridectomy was done over the upper third of the eye in the area of iris involvement. The epithelial membrane extended over the pupillary edge of the iris and onto the hyaloid face of the vitreous, so that as the iris forceps extracted the last of the tissue, formed vitreous was lost. The patient was seen last in May 1956, about two and a half years after the removal of the epithelial downgrowth. His vision was still 20/20 and there was no evidence of return of epithelial downgrowth.

Calhoun[3] has recently advocated an intriguing technique for establishing a diagnosis of epithelial downgrowth. He makes a small incision at the limbus, inserts a one-millimeter curet into the anterior chamber, and scrapes the back of the cornea in the area of suspected involvement. The cells thus obtained are placed on a glass slide, stained, and examined immediately. I have followed a

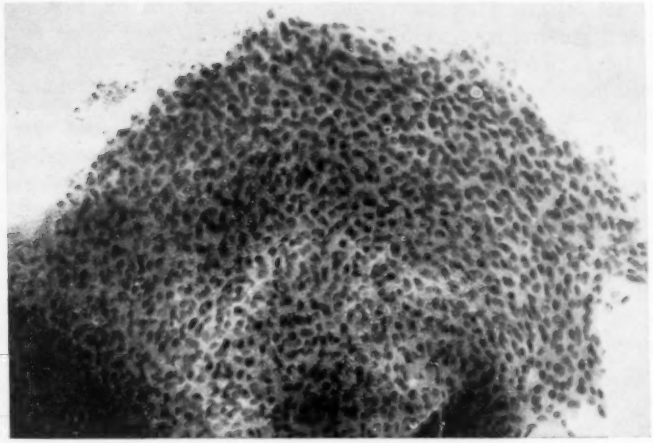


FIG. 3—Epithelial downgrowth from the anterior chamber. (× 120)

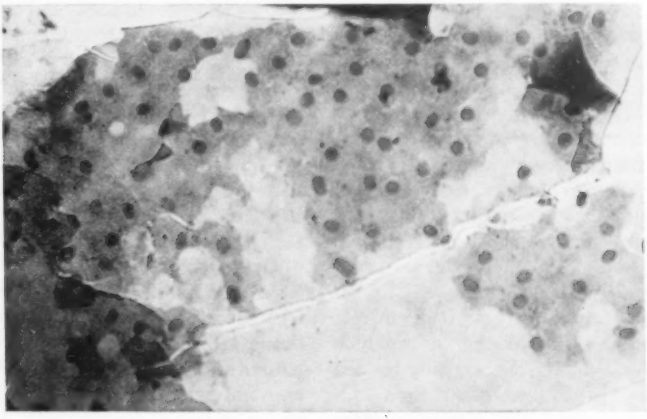


FIG. 4—Endothelium from back of cornea. (× 120)

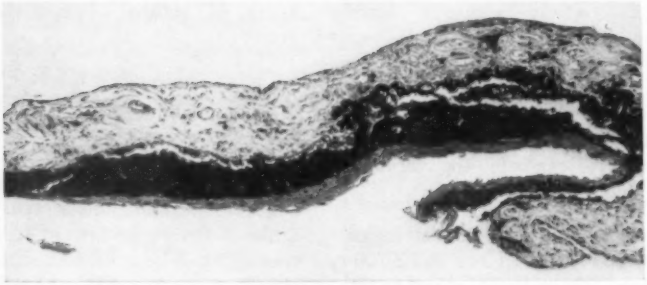


FIG. 5—Surface epithelium on pigment epithelium of iris. Same case as illustrated in figure 3. (× 40)

similar procedure in two cases but have made a slightly larger opening into the eye. Epithelium can be differentiated readily from endothelium in the tissues obtained for biopsy (figs. 3 and 4). If it is possible to obtain a piece of iris from the involved area, this material may further confirm the diagnosis (fig. 5).

It is suggested, therefore, that in the patient with a questionable diagnosis of epithelial downgrowth, tissue from the lesion be taken and studied at once. If the diagnosis is obvious from clinical examination, or if results of the biopsy are confirmatory, and if the membrane does not involve over one third of the anterior chamber, then surgical removal is indicated. Patients with pre-existing glaucoma and extensive involvement of the anterior chamber probably are not satisfactory candidates for surgical removal of the membrane.

Retinal Detachment

The problem of retinal detachment in aphakic eyes is an involved one. It would take an extensive discussion to cover the pathogenesis, clinical manifestations, pathology, and treatment of this subject. Therefore, only brief answers will be given to the following questions: (1) What is the relation of cataract extraction to retinal detachment in aphakic eyes? (2) What are the factors in aphakic eyes that predispose to retinal detachment? (3) What can be done to prevent retinal detachment in aphakic eyes?

The first of these questions can be answered by referring to two studies, one by Schepens[22] from the Retina Service of the Massachusetts Eye and Ear Infirmary, and the other by Welch[28] from the Retinal Service of the Wilmer Ophthalmological Institute.* The similarities of the findings in these two studies are striking. Seven hundred and thirty-six cases of retinal detachment were reviewed in the two studies (table II). One hundred and sixty-six, or 22 per cent, of these were in aphakic eyes following extraction for senile cataract. The high percentage of aphakic eyes in this group of cases of retinal detachment indicates that there is a definite relationship between retinal detachment and eyes with senile cataract or aphakia.

The time interval between cataract operation and the onset of the detachment is interesting. In 19, or 27.5 per cent, of the patients in Schepens' series, and in 21, or 27.6 per cent, of Welch's cases, detachment occurred within three months after operation. The time interval in these cases strongly suggests that aphakia in some way contributed to the detachment. In about 50 per cent of the patients, detachments occurred within one year after extraction. In the remaining 50 per cent, the detachments occurred one to eighteen years after extraction (table III).

There is evidence that the mechanics of lens extraction or aphakia are not always responsible for detachment. Schepens found the detachment was present before cataract extraction in 19 patients. This group comprised 21.5 per cent of his patients operated on for aphakic detachment, and it was 5 per cent of his entire group of retinal detachment cases. Similarly, there were 18 patients, or 5 per cent, of the 349 patients with de-

*Welch reviewed all of the retinal detachments operated on for reattachment in the Wilmer Ophthalmological Institute during the period of January 1953 through August 1956. Most of these patients were seen in the Retinal Service, which is under the direction of Dr. L. Harrell Pierce.

TABLE II

PERCENTAGE OF APHAKIC DETACHMENTS IN PATIENTS WITH RETINAL DETACHMENT

STUDY	TOTAL NUMBER DETACHED RETINAS	APHAKIA (SENILE CATARACT)	PERCENTAGE
Schepens	387	83*	21
Welch	349	83	24
Total	736	166	22

*At least 5 of the 88 aphakic eyes with retinal detachment reported by Schepens were not eyes which had had extraction for senile cataract

TABLE III

TIME RELATION BETWEEN CATARACT EXTRACTION AND RETINAL DETACHMENT

TIME OF ONSET OF RETINAL DETACHMENT	SCHEPENS CASES		WELCH CASES	
	NO.	%	NO.	%
Less than 3 months	19	27.5	21	27.6
3 months to 1 year	16	23.2	15	19.6
Over 1 year	34	49.2	40	52.6
Total	69		76	

TABLE IV

LOCATION OF RETINAL BREAKS IN APHAKIC DETACHMENT

LOCATION	SCHEPENS CASES		WELCH CASES	
	NO.	%	NO.	%
Near Ora	52	66	4	5.7
Mixed	18	23	5	7.3
Equator	9	11	53	75.7
Unknown			8	
Total	79		70	

tachment in Welch's series who had reattachment operations in eyes with senile cataracts. Also, Schepens notes that there is another finding that suggests an unusual structural abnormality in aphakic eyes. In his group of aphakic eyes, the majority of the breaks in the retina (66 per cent) occurred near the ora serrata; whereas, in phakic eyes the majority of breaks occurred near the equator. Here Schepens' figures markedly differ from those of Welch, for in the latter group, breaks were found in 53, or 75 per cent, at the equator (table IV).

What are the factors in aphakic eyes which predispose to retinal detachment? The possibilities may be listed under four general headings. First, Schepens is of the opinion that detachment in aphakia is not generally the result of cataract extraction. He thinks that many eyes with senile cataract also have low-grade inflammatory or degenerative changes in the retina near the ora serrata which predispose to detachment. Extraction of the lens is merely a complicating factor which precipitates the course of a slowly progressive detachment. In support of this idea, he mentions that

42 per cent of his patients with aphakic detachment who were carefully examined with a slit lamp showed signs of inflammation. He also found frequent evidence of low-grade inflammatory or degenerative changes in the far periphery of the fundus in these patients. Such findings may well be a factor in some cases of aphakic detachment; however, the relatively high percentage of detachment in aphakic eyes as compared to phakic eyes with cataracts would suggest that in many cases, aphakia contributes in some way to the detachment.

Second, there is the possibility that the mechanical trauma of lens extraction produces the retinal separation. The time interval, however, of several months to years between the extraction and the onset of the usual detachment would indicate that this trauma is not of major importance.

The question of extracapsular versus intracapsular cataract extraction in the production of detachments should be mentioned merely to be set aside. Many studies have shown that the percentage of retinal detachments is approximately the same after both types of extraction. Two sets of figures will be cited at this time. Hughes and Owens[10] found, in a review of 1,650 aphakic eyes, that detachment occurred in 10 eyes (1.6 per cent) after 639 extracapsular extractions, and in 14 eyes (1.4 per cent) after 1,011 intracapsular extractions. Nonnenmacher,[18] in a similar study, noted that 30 eyes (3.6 per cent) in a group of 844 extracapsular extractions developed detachments; 19 eyes (1 per cent) in a group of 1,975 intracapsular extractions, developed a similar lesion. In this latter study, in patients with myopia of over 10 diopters, 12 of 32 eyes developed retinal detachments after extracapsular extraction, and only 3 of 104 after intracapsular operation.

The fourth possibility is that some abnormality in the aphakic eye is responsible for the detachment. Patients in this category should be divided into two groups, those who have had complications at or immediately after extraction, and those who have had uncomplicated operations and postoperative courses. It has been shown clearly that loss of vitreous at the time of operation greatly increases the incidence of detachment.[10] Chronic postoperative iridocyclitis from retained lens capsule, iris prolapse, extensive hemorrhage, and low-grade infection, or other causes, probably also increase the chance of retinal separation. In these patients, retraction of vitreous is a most important factor.

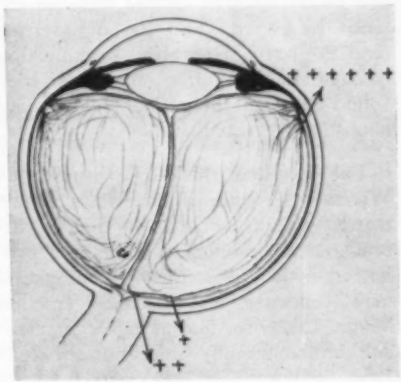


FIG. 6—Diagram of vitreous adhesions and structure in normal phakic eye.

One must visualize clearly the structure and the anatomical attachments of the vitreous to understand the process of vitreous retraction (fig. 6). Friedenwald and Stiehler[5] in 1935 demonstrated that vitreous is composed of concentrically arranged protein sheets of submicroscopic thickness. These sheets are separated from one another by a very small distance. In the central portion of the vitreous they lie roughly 3 mm. apart, but near the surface and also near the

canal of Clouquet they are much more closely packed. Spaces between these sheets are filled with a viscous fluid. This structure is attached firmly to the retina at the pars plana ciliaris, and is attached less firmly at the disc and possibly in the macular area.[6] Teng and Chi[24] have shown that with advancing age the attachment of the vitreous extends backward from the ora serrata onto the retina from 1 to 2 mm. Also, isolated abnormal attachments have been found between the retina and vitreous almost to the equator.[23]

The excellent histologic studies of Wadsworth[26] and Guyton[7] have shown that if vitreous is lost at the time of cataract extraction, or if there is a prolonged iridocyclitis, the vitreous sheets may condense and produce traction bands. Likewise, fibrous tissue may result either from a migration of cells from the corneal wound or from an accumulation of inflammatory cells on the condensed strands of vitreous. These may contract with time to produce taut bands. Thus, in the elderly patient whose vitreous is adherent to the retina behind the ora serrata and who has abnormal attachments of the vitreous to the retina, contraction of vitreous strands may produce retinal holes and detachment (figs. 7 and 8).

The course of events which produces detachments in eyes following uncomplicated cataract extraction, especially those that occur more than a year after extraction, is not clearly understood. It has been pointed out that abnormal attachments between the vitreous and retina increase with age. It is known also that peripheral cystic degeneration of the retina, especially on the temporal side of the eye, increases with advancing age. Prolapse or herniation of the vitreous into the anterior chamber, posterior detachment and syneresis of the vitreous are common findings after cataract extraction.[12] These changes produce more mobility of the vitreous[8] and, therefore, may cause abnormal traction on a weakened retina (figs. 9 and 10). The combination of these disturbances, plus the possibility of a low-grade inflammatory reaction in the periphery of the retina, may account for retinal detachment following apparently uncomplicated cataract extraction.

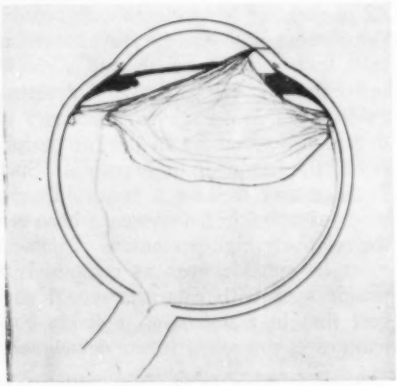


FIG. 7—Diagram of vitreous adhesions and bands following loss of vitreous at time of cataract extraction.

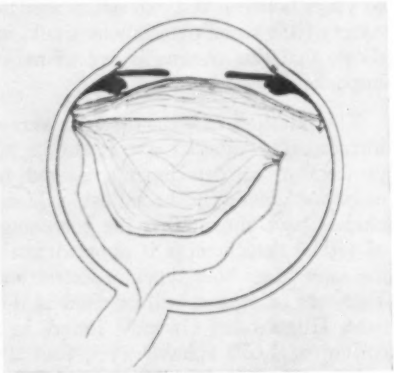


FIG. 8—Diagram of vitreous bands and contractions with retinal detachment following postoperative iridocyclitis.

What can be done to prevent retinal detachment in aphakic eyes? Again, this

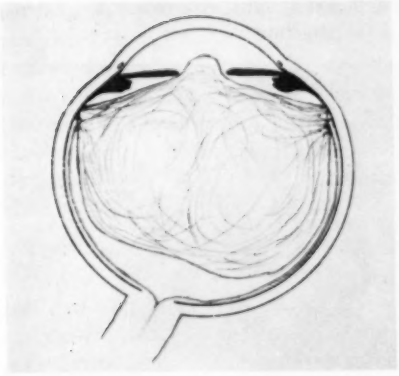


FIG. 9—Diagram of vitreous changes after an uncomplicated cataract extraction, with the patient lying on his back.

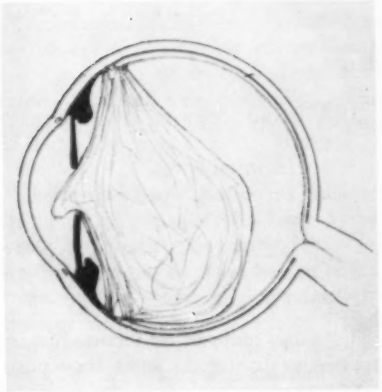


FIG. 10—Diagram of vitreous changes after an uncomplicated cataract extraction, with the patient standing.

is a complicated problem that cannot be answered at this time. It should be remembered that retinal detachment is more frequent in eyes with senile cataracts and aphakia than in normal eyes. Therefore, periodically the periphery of the retina in these patients should be studied. Retinal holes or subclinical detachments thus may be detected and operated upon. This applies especially to those patients who have had a detachment in one eye, or who have had complications at or immediately following cataract extraction. Postoperative uveitis should be controlled as much as possible, according to the suggestions of Hogan.[9]

It has been pointed out that the loss of vitreous at the time of operation greatly increases the incidence of retinal detachment after cataract extraction. The mechanics whereby this loss produces detachments have been discussed. Therefore, if vitreous is lost at the time of extraction, it would appear to be of value to free the wound of vitreous strands as far as possible. This can be done to some extent by closing the wound as tightly as possible with four or five corneoscleral sutures. The temporal suture is left untied. The exposed strands of vitreous are picked up with a tightly wound cotton applicator and cut as near the section as possible. Air then is injected into the anterior chamber. A thin iris spatula is inserted through the temporal edge of the wound and passed under the corneoscleral lip for the full extent of the section and down into the inferior part of the anterior chamber (fig. 11). During this pro-

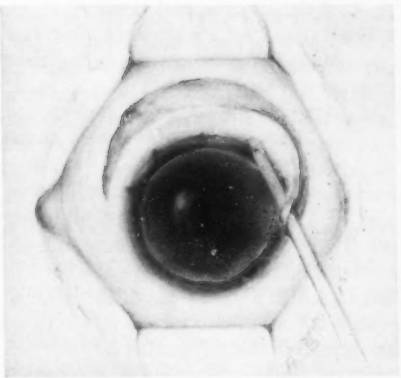


FIG. 11—Removal of vitreous from cataract incision. Anterior chamber has been filled with air, and iris spatula is passed under scleral lip of incision.

cedure, one usually can observe vitreous strands on the iris spatula being pulled out of the wound (fig. 12). If the air is lost from the anterior chamber during this last maneuver, more air is inserted. The head of the table or the patient's head then is elevated to allow the bubble of air to move between the wound and the vitreous. If the air does not float up, the spatula may be reinserted and another attempt made to remove the vitreous strands from the wound. If it does migrate up, the temporal suture is tied. The patient then is returned to his room, and his head is kept elevated so that the air continues to protect the wound from the vitreous. This procedure does not eliminate all vitreous adhesions to the incision, but it will reduce the extent of the attachment.

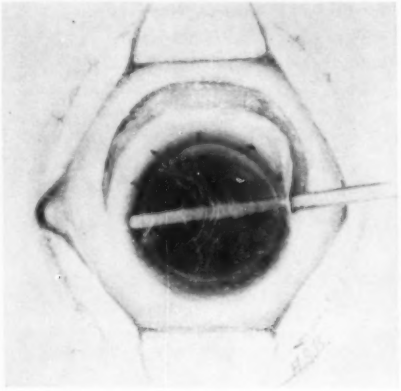


FIG. 12—Vitreous strands on iris spatula.

Corneal Edema

Persistent corneal edema following cataract extraction is an infrequent but troublesome problem. The abnormalities which produce the lesion may be classified as follows:

I. Corneal edema during the immediate postoperative period.

II. Persistent or late corneal edema.
- A. A defect in wound closure.
- B. Excessive trauma to the posterior surface of the cornea at the time of operation.
- C. Aggravation of abiotrophies.
  1. Progression of Fuchs's endothelial dystrophy.
  2. Progression of endothelial change after long-standing uveitis.
  3. Progression of endothelial change after long-standing glaucoma.
  4. Progression of endothelial change on the posterior surface of the graft after penetrating corneal transplant.
- D. Vitreous in contact with the cornea.
  1. In wound area.
  2. In central area of cornea.
     a. Early.
     b. Late.
- E. Foreign body in the angle of the anterior chamber.

The causes and clinical picture of corneal edema during the immediate postoperative period have been described by McLean.[16] A transient edema of the cornea may occur after delayed closure of the posterior lip of the incision. Normally the healing of the corneal incision begins by a fibrinous union of the superficial part of the wound, leaving an inverted V-shaped gape posteriorly. Occasionally, foreign substances, such as lens capsule, vitreous, iris, and conjunctiva, may be included in the wound. These tend to delay healing and produce a more prolonged edema of the cornea. Excessive mechanical trauma to the endothelium, either by manipulation with

instruments or by irrigation of the anterior chamber with saline, will produce a corneal clouding which may be slow to clear. Occasionally, rupture or tears in Descemet's membrane may occur. If the endothelium is healthy, these changes are repaired usually in three to four weeks after operation.

The most frequent cause of persistent corneal edema after an uneventful cataract extraction is an abiotrophy of the endothelium which exists prior to surgery. Irvine and Irvine[11] have described such changes in eyes with early Fuchs's endothelial dystrophy, chronic uveitis, and chronic glaucoma. They point out that the principal histologic defect is a flattening and a reduction in the number of endothelial cells. The endothelium that covers a penetrating corneal graft also appears to be more susceptible to trauma than that in a normal eye. This is especially true during the first year after transplantation.

The incision of choice for cataract extraction in patients who have a suspected endothelial abiotrophy, is a small deep scleral section made by the *ab externo* method, entering the anterior chamber just at the root of the iris or even slightly over the ciliary body. This procedure has been described in detail by McLean.[15] The advantages of the technique are several. First, no instrument need be inserted under the cornea, for the lens must be removed by the sliding method. Second, the posterior lip of the section is placed in the sclera, where aqueous is not absorbed as readily as it is in the corneal stroma. Thus, the danger of persistent gaping of the posterior lip of the wound or vitreous adherence to the incision is lessened. Finally, the arc of the section is much less than that in a corneal section. In these patients, the anterior chamber should be filled with air at the end of the operative procedure to prevent vitreous from touching the back of the cornea during the postoperative course.

When the hyaloid membrane or heavy vitreous strands adhere to the back of the cornea, there is usually a resultant corneal edema. This has been described clearly by Reese.[21] Such adhesions are more likely to take place if the contact persists from the time of operation than if there has been a delayed collapse of the anterior chamber. This indicates that damage to the endothelium plays a part in these lesions. Diffuse corneal edema occurs more frequently following adhesions of the vitreous to the wound if there is an early abiotrophy of the endothelium. Vitreous may adhere also to the central portion of the cornea. In these cases there may be a localized central area of edema for several months before the lesion spreads to other parts of the cornea.

The cause of such corneal change following vitreous adhesions is a disturbance in the normal deturgescence mechanism of the endothelium. Treatment of this condition falls into several categories. First, if the vitreous adhesion is central and has persisted for only a few weeks to a month, the lesion can be corrected by draining fluid vitreous or semifluid vitreous from the eye through the pars plana. Air then is injected into the anterior chamber, forcing the hyaloid membrane away from the cornea. If the adhesions are from several months to a year old, this procedure will not break the contact. In five patients with vitreous adhesions and corneal edema of six months to one and a half year's duration, I have opened the eye and removed the vitreous from the back of the cornea by grasping the strands with flat-bladed forceps and pulling the fibers free from the cornea. The anterior chamber then was filled with a large amount of air, and the patient was kept flat during the

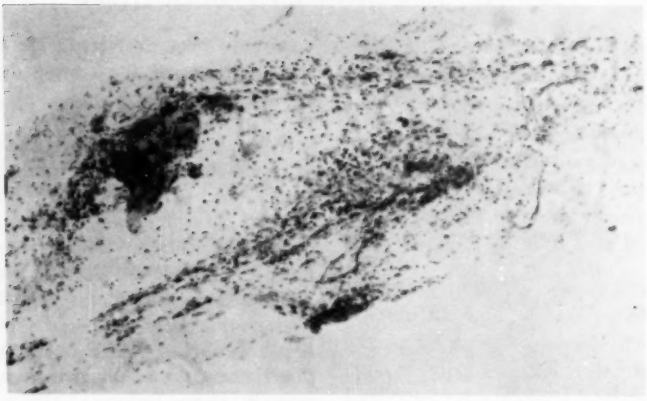


FIG. 13—Vitreous removed four months after cataract extraction, showing inflammatory and pigment cells. (× 40)

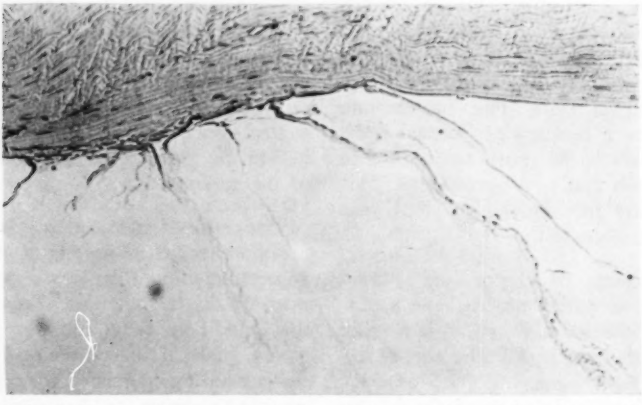


FIG. 14—Vitreous adhesion to cornea after cataract extraction (Wadsworth). (× 40)

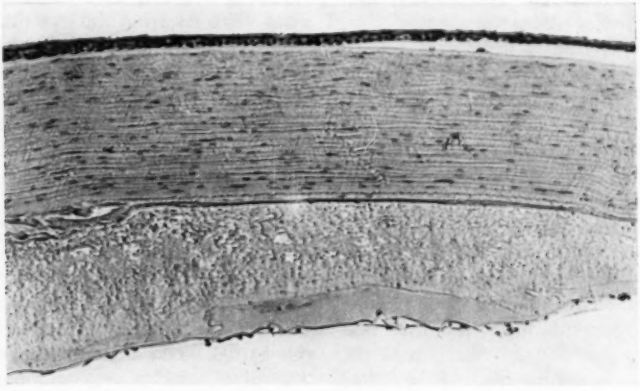


FIG. 15—Same case as that illustrated in figure 14. Pocket of edema on posterior surface of cornea (Wadsworth). (× 40)

postoperative period until the air had absorbed. This procedure prevented reattachment of the vitreous to the cornea, but the corneal edema has persisted, indicating that irreparable damage to the endothelium had taken place.

Histologic study of the removed vitreous strands showed thickened fibers which frequently contained inflammatory cells (fig. 13). Wadsworth[27] has described the histologic appearance of an eye of a patient who had persistent corneal edema following vitreous adherence to the posterior surface of the cornea. In this eye there was marked edema, or a collection of fluid between the posterior corneal stromal layers and Descemet's membrane (figs. 14 and 15).

Hogan[9] has performed 8 mm. penetrating corneal transplants on five patients with persistent corneal edema after cataract extraction. The postoperative visual acuity ranged from 5/200 to 20/40. While these results leave something to be desired, it is very encouraging to know that some improvement can be obtained in these very complicated cases.

Foreign bodies, such as glass from the irrigator tip or from the tube that contains the sutures, may fall into the anterior chamber and lodge in the angle below. This will produce a localized corneal edema.

Anterior Chamber Hemorrhages

The incidence of severe anterior chamber hemorrhage should be reduced almost to zero if the cataract incision is placed properly and adequate corneoscleral sutures are used. It has been shown by McLean[15] that unless there are new-formed vessels on the iris, or unless an iridodialysis is done at the time of surgery, bleeding into the anterior chamber usually comes from the cor-

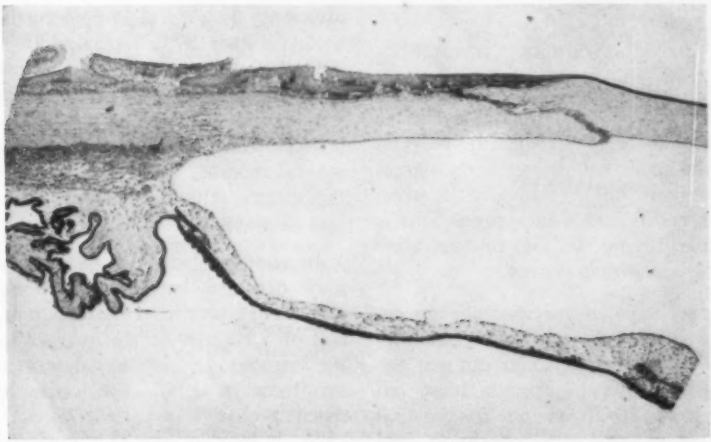


FIG. 16—Cataract incision at 12 o'clock position. Patient died thirty days after operation. (× 40)

neoscleral wound. Blood vessels in the normal eye are present only in the superficial tissue at the corneal edge of the limbus. This is especially true above. Thus a section, even when it is made under a limbal-based flap, should be entirely in avascular tissue (fig. 16). At the inferior edge of the section on the nasal and temporal sides, the limbus becomes more narrow. Unless one is careful to dissect the conjunctival flap into the cornea for a short distance at the 3 and 9 o'clock positions, deep scleral vessels may be cut. These vessels can produce considerable bleeding into the anterior chamber at the time of operation or during the postoperative period if the wound is disturbed. In patients with long-standing diabetes, blood dyscrasias or hypertension, or in eyes that are congested or have had a previous inflammatory reaction, care should be taken to control the bleeding at the time of operation. In this same group of patients, if the corneal endothelium is in good condition, the section should be placed further in clear cornea than normally. Hemorrhages that occur during the postoperative period should be allowed to absorb spontaneously unless they are so massive that secondary glaucoma ensues and cannot be controlled with Diamox.®

Changes in the Macula

Changes that occur in the macula following cataract extraction may be classified as follows:

I. Acceleration of a pre-existing change, i.e., early senile degeneration, hemorrhagic disciform degeneration, or myopic degeneration

II. Macular edema
   A. Hypotony
   B. Iridocyclitis
   C. Vitreous syndrome (Irvine)

Some patients with senile cataract also have early degenerative lesions in the macular area. Frequently cataract extraction does not change the progress of the lesions, but occasionally the process is speeded up by extraction. This is particularly true if the postoperative course is somewhat stormy.

Another type of macular change occurs in patients who have persistent hypotony or iridocyclitis after cataract extraction.[4] In some instances, these patients have 20/20 vision for several weeks or months after operation, and then the vision begins to decline.[17] At first it is difficult to detect any change in the macular area, but if the lesion continues, the foveal reflex is lost and a slight elevation of the macula can be seen. This is detected best with the Hruby lens or contact lens and slit lamp. The clinical appearance of such changes is similar to central serous chorioretinopathy. Histologically, there is a localized flat serous detachment of the macular area (fig. 17). If the hypotony is controlled, either by a repair of the leaky wound or from spontaneous normalization of tension, or if the iridocyclitis subsides, the vision may return to normal. However, if the defect persists for several months, cystic changes occur in the macula with a resultant permanent loss of vision.

In another group of patients, vision may decrease suddenly from several months to a year after extraction as a result of a rupture of the hyaloid face of the vitreous. Irvine[12] has described this syndrome in detail. The cause of the macular change in patients is not quite clear. It may be due to a posterior detachment of the vitreous with traction

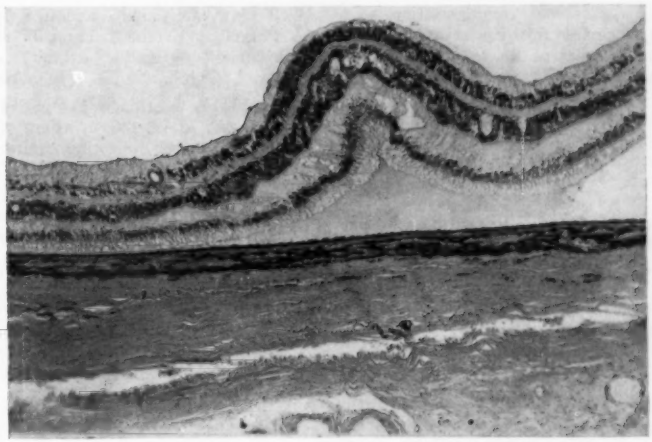


FIG. 17—Flat detachment of macula in eye with postoperative iridocyclitis after cataract extraction.

on the macular area, or it may be due to an accompanying hypotony or iridocyclitis.

REFERENCES

1. Blodi, Frederick C.: Failure of the cataract extractions and their pathologic explanation, J. Iowa M. Soc., 44:514-516 (Nov.) 1954.
2. Calhoun, F. Phinizy, Jr.: The clinical recognition and treatment of epithelization of the anterior chamber following cataract extraction, Tr. Am. Ophth. Soc., 47:498-553, 1949.
3. ———: Personal communication.
4. Dellaporta, Angelos: Fundus changes in postoperative hypotony, Am. J. Ophth., 40:781-785 (Dec.) 1955.
5. Friedenwald, Jonas S., and Stiehler, R. D.: Structure of the vitreous, Arch. Ophth., 14:789-808 (Nov.) 1935.
6. Grignolo, A.: Fibrous components of the vitreous body, A.M.A. Arch. Ophth., 47:760-774 (June) 1952.
7. Guyton, Jack S.: Complications after cataract extraction: pathologic aspects. In Symposium: Cataract Extraction, Tr. Am. Acad. Ophth., 58:397-407 (May-June) 1954.
8. Hilding, A. C.: Alterations in the form, movement, and structure of the vitreous body in aphakic eyes, A.M.A. Arch. Ophth., 52:699-709 (Nov.) 1954.
9. Hogan, Michael J.: Companion paper, p. 33.
10. Hughes, William F., Jr., and Owens, W. C.: Extraction of senile cataract: a statistical comparison of various techniques and the importance of preoperative survey, Am. J. Ophth., 28:40-49 (Jan.) 1945.
11. Irvine, A. Ray, and Irvine, A. Ray, Jr.: Variations in normal human corneal endothelium: a preliminary report of pathologic human corneal endothelium, Am. J. Ophth., 36:1279-1285 (Sept.) 1953.
12. Irvine, S. Rodman: A newly defined vitreous syndrome following cataract surgery, Am. J. Ophth., 36:599-619 (May) 1953.
13. Maumenee, A. Edward: Unpublished figures.
14. Maumenee, A. Edward, and Shannon, C. Richard: Epithelial invasion of the anterior chamber, Am. J. Ophth., 41:929-942 (June) 1956.
15. McLean, John M.: Extraction in complicated cases. In Symposium: Cataract Extraction, Tr. Am. Acad. Ophth., 58:371-377 (May-June) 1954.
16. ———: Companion paper, p. 20.
17. Nicholls, John V. V.: Concurrence of macular edema with cataract extraction, A.M.A. Arch. Ophth., 55:595-604 (May) 1956.
18. Nonnenmacher, Heinz: Über Netzhautablösungen nach Staroperationen, Klin. Monatsbl. Augenh., 118:363-369, 1951.

19. Patz, A.: Personal communication.
20. Perera, Charles A.: Epithelium in the anterior chamber of the eye after operation and injury, Tr. Am. Acad. Ophth., 42:142-164, 1937.
21. Reese, Algernon B.: Herniation of the anterior hyaloid membrane following uncomplicated intracapsular cataract extraction, Am. J. Ophth., 32:933-946 (July) 1949.
22. Schepens, Charles L.: Retinal detachment and aphakia, A.M.A. Arch. Ophth., 45: 1-17 (Jan.) 1951.
23. ———: Clinical aspects of pathologic changes in the vitreous body, Am. J. Ophth., 38:8-21 (July) 1954.
24. Teng, Chin Chiang, and Chi, Helen H.: Pathology of the vitreous in retinal detachment (scientific exhibit), Tr. Am. Acad. Ophth., 59:594 (July-Aug.) 1955.
25. Theobald, Georgiana D., and Haas, Joseph S.: Epithelial invasion of the anterior chamber following cataract extraction, Tr. Am. Acad. Ophth., 52:470-485 (May-June) 1948.
26. Wadsworth, Joseph A. C.: Etiology and pathology. In Symposium: Retinal Detachment, Tr. Am. Acad. Ophth., 56:370-397 (May-June) 1952.
27. ———: Personal communication.
28. Welch, R. B.: Personal communication.

ON CIGARETTE SMOKING, BRONCHIAL CARCINOMA AND CILIARY ACTION

Time Element in the Exposure to Carcinogenic Substances and Its Relation to Carcinogenesis

A. C. HILDING, M.D., PH.D.
DULUTH, MINNESOTA

MUCH has been said in the past about the relation of chronic irritation to the development of malignant processes. Recent concepts are more specific and put carcinogenesis on a physicochemical basis in which the time element plays a big role.

Carcinoma in the tracheobronchial tree tends to occur in certain areas, and the studies described in this report indicate that the ciliary mechanism may be related to this pattern of distribution and may be the agent which furnishes the necessary time factor for carcinogenesis.

Butenandt[6] has postulated a growth-control substance within the cells, which, in some way, is altered to permit uncontrolled growth and division of cells. He does not know whether this material is in the cytoplasm or in the nucleus.

Arley and Iversen,[1,2,3,14,15] in a series of articles describing what they term the "hit theory," postulate certain control centers in the cell nuclei in the form of giant molecules which make "quantum jumps" when acted upon by certain chemicals, x-ray neutrons, and viruses. How these quantum processes, once they have taken place, can induce biologic changes in a large number of cells to make macroscopic tumors, they maintain, is one of the most fundamental unsolved problems in biology. Butenandt thinks that a minimum of one hundred to one thousand altered cells is necessary to produce a neoplasm. Arley and Iversen conceive of the action upon the "cancer control center" as something similar to the action of mutagenic agents upon the genes; the two are not the same, however, because most carcinogenic substances are weakly mutagenic. They place the action on the cancer control center upon a mathematical basis, expressed in equations in which two factors — time and concentration — play a prominent role.

Are the findings in research correlating cigarette smoking and bronchogenic carcinoma consistent with this concept? From this and previous studies,[10] it seems to me that they might well be.

PRESENT STUDY

The present study describes the physiology of ciliary streaming and drainage in the tracheobronchial tree and the manner in which deposited materials are removed normally. It points out several ways in which inhaled carcinogenic substances, of whatever nature, might accumulate and pause for a time at certain spots.

It will be recalled that a thin film of

From the Research Laboratory, St. Luke's Hospital, Duluth 11, Minnesota. Work supported by grants from the Louis W. and Maud Hill Family Foundation of St. Paul, the Edward C. Congdon Memorial Trust, Miss Elisabeth Congdon, and The Women's Service Guild of St. Luke's Hospital.

Presented at the Sixty-First Annual Session of the American Academy of Ophthalmology and Otolaryngology, October 14-19, 1956, Chicago.

rather viscid mucus overlies the ciliated respiratory epithelium and that this blanket, moving continuously upward toward the larynx, motivated by ciliary action, constitutes the ciliary stream. The cilia extend down as far as the respiratory bronchioles, and it is, presumably, here that the ciliary stream begins.

MATERIAL AND TECHNIQUE

The material upon which these findings are based came from all or part of the lower respiratory tracts removed at 21 necropsies and from 73 cows and 49 calves. The tracheas and bronchial trees were opened and examined for ciliary streaming as soon after death as practicable. The flow was made visible by applying droplets of India ink to the surface of the mucous blanket. Observations on ciliary streaming were made both through a Greenough-type dissecting microscope and grossly.

The cilia continue their activity for many hours after death. Specimens from two autopsies showed active ciliated cells thirty-six hours after death, even though both of these bodies had been in a cold room for many hours. In the laboratory, the only care taken of the specimens was to place them in plastic bags and leave them at room temperature.

The mucous blanket behaves less dependably than the cilia. Sometimes it flows well for many hours postmortem; sometimes, on the other hand, when the surface looks glazed, it moves sluggishly or not at all. The information obtained from individual specimens was fragmentary, and it was necessary to examine many specimens and to piece the bits of garnered information together in order to obtain a picture of the physiology of ciliary drainage. Considerable information was obtained from some specimens, whereas many others furnished none. The data do not lend themselves to tabulation.

CILIARY STREAMING IN THE BRONCHIAL TREE

A description of ciliary streaming in the bronchial tree, as found in these specimens, follows:

The flow of the ciliary stream in the bronchial tree of man is directed generally upward against gravity. Paradoxically, downstream is up toward the larynx, and upstream is down toward the alveoli. The motive power for this upside-down stream is, of course, the cilia of the ciliated mucous membrane. Presumably the ciliary stream arises in the respiratory bronchioles, where the cilia begin (or end, depending upon the viewpoint).

Stream-bed

The flow arises in a stream-bed which is very wide but which rapidly narrows as it approaches the trachea. In a study reported some years ago, it was found that the total cross-sectional area of the trachea and bronchial tree remained approximately the same down to the bronchioles, about 1 mm. in diameter.[13] However, the aggregate of the circumferences of the bronchi at subsequent levels increased markedly as branching occurred. To illustrate: The trachea is approximately 50 mm. in circumference; this is the width of the stream-bed in which the mucous blanket flows. Each of the main bronchi is 35 to 40 mm. in circumference. The combined circumference of the two is about 75 mm. and, at this level, represents the width of the ciliary stream-bed. At each subsequent division, the aggregate of the circumferences grows greater (fig. 1). Even when calculated on the basis that the total cross-sectional area remains about the same down to the respiratory bronchioles, the aggregate of the circumferences of all of the respiratory bronchioles would be meters in extent. There is evidence that the cross-sectional area increases in the

small bronchioles less than 1 mm. in diameter,[18] and this would further increase the total circumference. Since all of these bronchioles are lined by ciliated epithelium, this would represent the width of the stream-bed at that level. The ciliary stream, then, begins in a stream-bed meters in extent and, in the comparatively short distance from the periphery to the trachea, narrows down to approximately 50 mm.

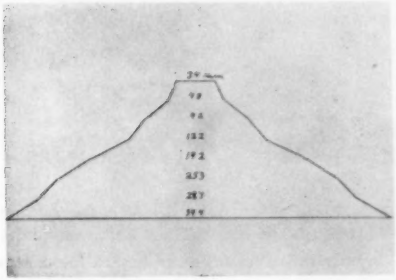


FIG. 1—Diagrammatic representation of the increase in the width of the stream-bed (summation of circumferences) using measurements of the left lower lobe at eight different levels in a 34-year-old man. The diameter of the tubes at the lowest level averaged 1.12 mm. A much greater increase occurs peripheral to this level.

Mucous Volume

All of the areas in this stream-bed are covered by the mucous blanket. Of necessity, the mucous blanket narrows as the stream-bed narrows; thus, the volume flow of mucus over a unit area, in a given time, in the trachea is many times greater than in a similar unit area in the smaller bronchi. Since there are mucus-producing glands all the way along from the respiratory bronchioles to the trachea (in fact, up through the larynx), the volume of mucus is further enhanced by any addition which these glands contribute en route.

Velocity of Flow

The velocity of ciliary flow in the trachea of these specimens varied from 0 to 36 mm. per minute. I measured it once through a bronchoscope in an unanesthetized dog that was particularly docile and cooperative. In this animal, the rate was from 14 to 15 mm. per minute. Dalhamn[7] found the rate in the tracheas of rats to be from 12 to 16 mm. per minute.

Similar to the speed gradient in the sinuses, the velocity of flow in the tracheobronchial tree probably increases progressively as the trachea is approached, but no satisfactory comparative measurements at different levels in the bronchial tree could be made in the material used in these studies.

OBSTRUCTIONS TO CILIARY STREAM

Bronchial Openings

In its course from the respiratory bronchioles to the esophagus, the ciliary stream encounters certain obstructions, among which are the bronchial openings. At first thought, it seems odd that bronchial openings could act as obstructions, but when the ciliary stream is observed in action, this phenomenon is quickly understood. In fact, it could not be otherwise. Consider the ciliary stream, for instance, as it flows through a segmental bronchus. It encounters the opening of a tributary bronchus, which joins the one under consideration. The mucous blanket, when it comes to this opening, does not span it in the form of a film but, at the upstream margin of the opening, ceases its axial progress, divides, and flows in two directions about the margins of the opening (fig. 2).

Ciliary Narrows

It is to be noted further that at this level, the width of the stream-bed is reduced by the dimension of the diameter of the opening of the tributary bronchus. Where two or more bronchi enter at approximately the same level, this narrow-

FIG. 2—(A) Left main bronchus of a cow, split open at the midposterior line and nailed out flat. Ink droplets had been placed on the surface of the main bronchus and in several of the tributary bronchi to indicate the manner of ciliary streaming toward the trachea. The streams tend to diverge on the anterior and lateral walls and to converge and meet at the posterior wall (here the two margins of the specimen). Each bronchial opening acts as an obstruction.

(B) Diagram of the details of flow about the bronchial openings. The mucous blanket must be torn asunder at the middle of the upstream margin of the opening, where a degree of slowing of the stream occurs. In the lowest bronchus and in the upper left bronchus can be seen the manner in which the ink-stained blanket drapes itself across the openings. Experimen s indicate that the axial direction of ciliary beat changes, as an opening is approached, to directions very much like those indicated by the arrows.

ing may be extreme. In one autopsy specimen, it was found that three tributary bronchi opened at about the same level into one of the large bronchi. The large bronchus at that level measured 23 mm. in circumference, but, of this, 18 mm. were taken up by the openings of the tributary bronchi, leaving only 5 mm. for ciliary streaming. In my own laboratory, such regions have been dubbed "ciliary narrows" (fig. 3).

To return to the division of the mucous blanket at the bronchial opening. This can best be illustrated perhaps by considering the coryna. At the coryna, the medial wall of each of the main bronchi ceases to exist. When the mucous blanket on the medial wall of the right main bronchus comes to the coryna, it divides near the middle of the coryna into an anterior and a posterior portion. The former flows out onto the anterior wall of the trachea, and the latter to the posterior wall. In a similar manner, the mucous blanket on the medial wall of the left main bronchus splits at approximately the same point on the coryna into two halves, the anterior one flowing to the anterior wall of the trachea, and the posterior one to the posterior wall. Thus, at approximately the middle of the coryna, there is a four-way split in the mucous blankets coming to

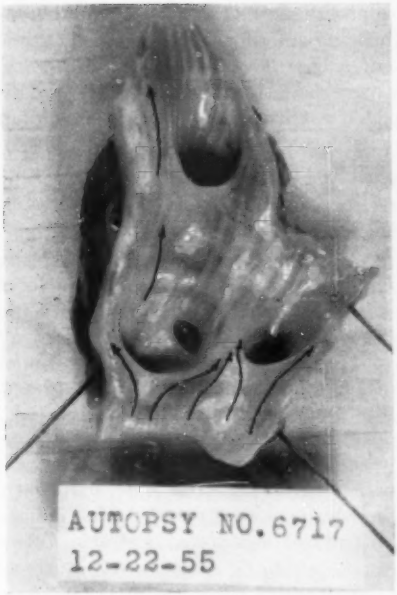


FIG. 3—Autopsy specimen of a bronchus 23 mm. in circumference, showing entrance of three tributary bronchi at about the same level, narrowing the available stream-bed to 5 mm., as indicated by the arrows. The flow about these bronchial openings seemed to be the same as in the animal. (By permission of Dr. Lennart Holmgren, Editor of Acta Oto-Laryngologica.)

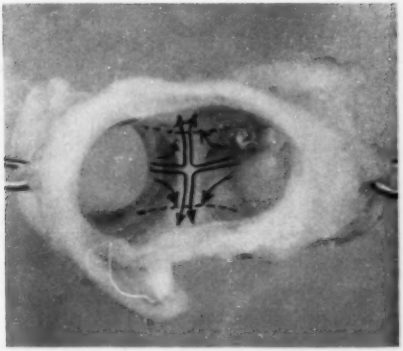


FIG. 4—Photograph of the coryna of a beef animal. The arrows indicate the four-way split of the mucous blanket that occurs not only at the coryna but upon the crescentic septum wherever two bronchi join. To determine whether this change of direction is due to traction upon the mucous blanket by cilia farther downstream or to the direction of beat of the cilia upon the coryna, an experiment was done incising the mucosa along the dotted lines and spreading the incision widely. The direction of flow did not change, and the ink used as an indicator collected at and spilled over the margin of the incision on the side of the coryna. (By permission of Dr. Lennart Holmgren, Editor of Acta Oto-Laryngologica.)

that point (fig. 4). This four-way split occurs throughout the tract wherever two bronchi join and is to be found approximately in the middle of the crescentic edge of the sharp septum formed by the junction.

When the divided stream has passed the opening of a tributary bronchus, the two halves do not converge again on the downstream side; rather, they continue to diverge, and the blanket for the downstream side is furnished from the tributary bronchus (fig. 2). In the cow, many tributary bronchi join the main bronchus in the anterior two thirds of its circumference. There are only a few small ones posteriorly. The divided streams flowing past these many bronchi diverge progressively upon the side walls and join again posteriorly, where the heaviest stream seems to flow. This posterior stream is carried past the coryna and up the posterior tracheal wall. A smaller anterior stream is formed at the coryna from the medial and anterior walls of the terminal portions of the main bronchi and some of the closest secondary bronchi.

It is of importance to know the mechanics of the division which takes place at the bronchial openings. It would be possible that flow past these openings might occur from traction alone on the mucous blanket, exerted by the cilia located at the two sides of the opening, all of which might be beating in the long axis of the air passage. The nonciliated areas in the nose are drained largely by traction exerted by the ciliated areas lying farther posterior. If the division were due to traction alone, one would think that the mucous blanket would have a tendency to span the opening.

This it does not often do. It usually clings closely to the sharp margin of the opening and flows in the two directions. The other possibility is that the direction of ciliary beat would change as the opening is approached, in order to direct the flow in the observed course.

Direction of Ciliary Beat. It was not easy to determine the direction of ciliary beat, and a great deal of time was spent in attempting to do so. Finally, in one animal specimen, a very good preparation for the Greenough microscope was obtained, showing that the direction of the ciliary beat actually does change. The mucous blanket in this specimen was washed away by Ringer's solution to remove the factor of traction. It was then observed that isolated bits of material, floating on the surface of the ciliary stream, continued to follow approximately the paths of the ciliary streaming before the blanket was removed. The cilia themselves were lightly stained and could be seen quite clearly. The wave fronts, which usually travel at right angles to the direction of beat, altered direction as the bronchial opening was approached, indicating that the ciliary beat had changed direction and was diagonal as the opening was neared. In the line leading directly to the middle of the bronchial opening, the cilia continued to beat in an axial direction almost until the margin was reached; then they changed quite suddenly and beat almost at right angles, half of them toward the right and the other half toward the left.

In another specimen, we dissected the coryna carefully, without touching the mucosa upon it, and isolated it from the trachea anteriorly and posteriorly by cutting away the mucous membrane. Thus the factor of traction was removed from the crescent itself. India ink was then placed upstream on the medial wall of both main bronchi. The lines of flow approaching the coryna described curves bending anteriorly and posteriorly to the cut edge of the mucous membrane, where the ink accumulated (fig. 4). This could not have been due to traction but must have been due to the diverging directions of the ciliary beat.

Whirlpool. Another phenomenon was observed, which may be the most significant finding in all of these studies. In a number of specimens, a tiny whirlpool was found exactly on the margin of the bronchial opening, where the four-way split occurred. In one, this whirlpool measured 0.25 mm. in diameter, and it was observed for an hour and a half, during which time it rotated continuously and then ceased. There was never any period during the hour and a half when the whirlpool was free of the ink indicator that had been placed upstream. Other

FIG. 5—Enlarged photograph of tiny whirlpool at the point of the four-way split on the septum where two bronchi join.

rotating whirlpools were observed at different times; one was observed until it dried up and stopped (fig. 5), and another was still rotating at the time the specimen was discarded. Similar round specks, just in the center of the four-way split, were seen in nearly a dozen other specimens, but none of these specks were rotating at the time they were observed.

Vocal Cords

Another obstruction in the ciliary stream is the squamous epithelium on the vocal cords. The stream flowing up the posterior wall of the trachea from the coryna passes into the interarytenoid area and to the posterior margin of the larynx and over into the esophagus. There is no interruption in this stream. The stream flowing up the anterior wall, however, ceases its axial progress when it comes to the squamous epithelium on the margin of the vocal cords, splits at the anterior commissure, and passes backward approximately at right angles to its former course, half upon each cord. The boundary between the squamous epithelium on the cords and the ciliated epithelium is very sharp. The upper limit of the ciliary flow on the cord is correspondingly sharp, and along this line, the axial progress is changed to an anteroposterior one. The flow on the lateral walls of the larynx describes a curved course directed backward toward the interarytenoid region. To be sure, these tests and findings were made upon the larynges of freshly killed calves. One cannot be sure that it is exactly the same before death (fig. 6).

An experiment was done in the larynx to test the direction of ciliary beat (fig. 7). It was concluded that the plane of ciliary beat upon and just below the vocal cords is no longer axial but is directed approximately in the lines of ciliary flow.

FIG. 6—Left half of the larynx of a freshly killed beef animal. The arrows indicate the direction of ciliary streaming. The sudden change of direction on the vocal cord coincides with the line along which the ciliated epithelium changes to squamous.

Squamous Islands

It has long been known that there are islands of squamous epithelium and epithelial metaplasia in the bronchial tree of many otherwise normal people. From the standpoint of physics, such islands would inevitably have some effect on the ciliary streaming. How much is problematic. It is not likely that complete cessation of axial flow would occur, as on the vocal cords, but some degree of slowing, with perhaps comparative stasis, would seem probable. Quite a number of experiments were done with deciliated islands[9] to study the effect on ciliary streaming. At such artificially deciliated islands — tiny circular spots from which the cilia of the surface cells

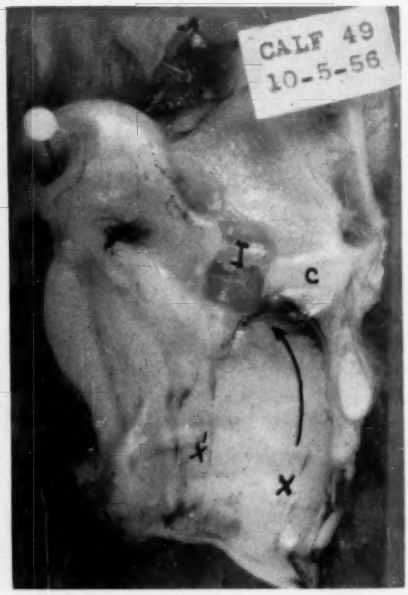


FIG. 7—A calf larynx, split in half in the midplane with as little trauma as possible. An experiment was designed to demonstrate whether the backward direction of flow was caused by traction upon the mucous blanket by the cilia in the interarytenoid area or by the direction of ciliary beat in the region inferior to the vocal cord. An axial incision (I) was made through the posterior third of the vocal cord (C) and through the epithelium for a distance both above and below the cord. One droplet of ink was placed at X and another at X^1. The one at X^1 flowed by ciliary action to the posterior interarytenoid area, where it can be seen. The direction of flow inclined away from the posterior lip of the incision. The one placed at X followed the course of the arrow and gathered at the anterior lip of the incision, at which it overflowed. Since there was no possibility of traction here, it was concluded that it must be due to the oblique direction of ciliary beat.

had been removed — the effect on the ciliary streaming was marked. Accumulations of the indicator, which occurred on these deciliated islands, sometimes remained for an hour or two. It cannot be assumed, however, that on the naturally occurring squamous islands the effect is so marked.

Abnormally nonciliated areas, such as those described by Ryan and McDonald[21] and Auerbach,[5] would undoubtedly also serve to cause stasis and accumulation of tar or any other inhaled carcinogenic substance.

This, then, is the picture of ciliary streaming in the bronchial tree in postmortem specimens, both animal and human, observed while the cilia were still active. It is, of course, possible that the details are different in the living organism.

DISCUSSION

Relation to Cigarette Smoking

What does ciliary streaming in the bronchial tree have to do with cigarette smoking? Nature has provided man with an efficient air-cleansing mechanism, which suffices to cleanse the inspired air of most pollution. Ordinary dust does not reach the lungs. But man has contrived to circumvent this air-cleansing mechanism by means of an ingenious little inexpensive device, which charges the inspired air with a variety of gases and finely divided, suspended, tar droplets, which travel as far as the inspired air goes. In previous studies, it has been determined that a substantial portion of the visible smoke from cigarettes is retained within the lungs in ordinary cigarette smoking.[11] In most smokers, a certain portion returns with expiration. This means that the air used for taking a puff of a cigarette is loaded with smoke all the way down as far as the inspired air goes and all the way back. Therefore, the distribution of the deposit must be widespread, but perhaps it is somewhat heavier in the proximal portions of the tract, which are exposed longer.

A simple experiment demonstrating deposition and retention of the tar can be done by any smoker. In the laboratory, the experiment was done under controlled conditions. The smoker took a two-second puff of smoke into his

mouth under a pressure of 75 mm. of water, and then he blew it directly out of the mouth. This gave a visual impression of the amount of smoke obtained. He then repeated the process, but, instead of blowing the smoke out, he inhaled it deeply into the lungs and held his breath for ten seconds. When the air was exhaled, it was practically free of smoke. Assuming that 95 per cent of the smoke was retained in ten seconds, it is easily calculated that approximately half of the tar is deposited in about one fourth of the time (fig. 8). In an ordinary respiratory cycle, the tidal air is not retained within the small air passages for two and a half seconds, but

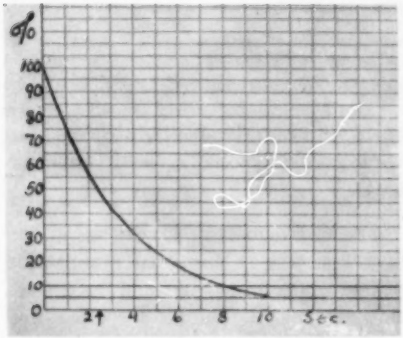


FIG. 8—Graph of the calculated rate of smoke deposit in the bronchial tree, assuming that about 94 or 95 per cent is deposited in ten seconds. (By permission of Dr. Lennart Holmgren, Editor of Acta Oto-Laryngologica.)

a smoker does not use an ordinary respiratory cycle when he takes a puff. He breathes more deeply and longer, savoring the smoke, and he might quite easily retain this smoke in the small passages as much as two and a half seconds. I think it would be no exaggeration to assume that from one third to one half of the tar from cigarette smoke is retained by the ordinary smoker.

It must not be forgotten that there are other compounds in cigarette smoke than the mixture we term tar. Some are quickly dissolved and absorbed, like nicotine. What becomes of the others, I do not know. I have been told by chemists that the arsenic compounds, which have been discussed recently,[22] either might occur as a free gas or might be included in the tar, depending upon the temperature of burning or other circumstances.

FIG. 9—Spot of spontaneous stasis, 2 mm. in diameter, found in the trachea of a cow. It can readily be seen how the mucous blanket, with its contained ink, accumulated in the form of a crescent on the upstream side. This spot was taken for histologic examination. The mucous blanket was found to be intact, but the ciliated cells at the surface were somewhat disarranged and the cilia were gone. The epithelium was not of the squamous type.

The tar film floating upon and incorporated with the mucous blanket would meet the same obstructions encountered by the blanket and would tend to pause or stop at the same points at which the blanket stops en route from the respiratory bronchioles to the esophagus. Some experiments, previously reported,[9] demonstrated crescentic accumulation of tar on the upstream side of artificially deciliated islands. It is probable that there would also be some accumulation upon naturally occurring squamous islands, where the direct motive power to the mucous blanket is absent and it must move across the nonciliated area by traction from the surrounding area (fig. 9). In experiments with India ink in

our specimens, it was found that the ink tended to accumulate on the upstream side of bronchial openings just where the mucous blanket splits. This did not always happen and was never seen to occur on the coryna, but it did occur on some of the lips of bronchi tributary to the main bronchi. This might have been artifact, but, from the standpoint of physics, it would seem that there would have to be a slowing of the stream at the point where the blanket splits. Further, tar might accumulate just as readily as the ink indicator in the whirlpools observed in the middle of the bronchial septa. If this should occur, not only would the tar be retained for a prolonged period of time in one spot, but it would be thoroughly stirred as it lay there, thus allowing time for slowly acting chemical reactions and furnishing optimum conditions for solution. At the vocal cords, also, where the India ink indicator demonstrates that the mucous blanket splits and accumulates, any contained tar must behave similarly and be applied to the cells at that point for more or less extended periods of time.

Distribution of Bronchogenic Carcinoma

Moersch and McDonald have mapped the distribution of different types of pulmonary carcinoma[19] (fig. 10). The squamous-cell type tends to occur among the larger bronchi in the hilus of the lung, the area where the mucous blanket has been gathered from a very wide stream-bed, with everything it contains, into a comparatively narrow one. This is where the large bronchial openings, which act as obstructions, occur and where the ciliary narrows, as well as the islands of squamous epithelium, are found. In the trachea, carcinoma is comparatively infrequent. In the trachea there are no tributary bronchi to act as obstructions. Carcinoma is encountered again with considerable frequency on the vocal cords, especially on the anterior half.

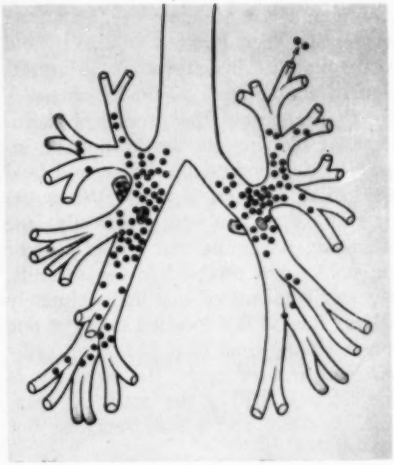


FIG. 10—Distribution of squamous cell carcinoma, as found by Moersch and McDonald.[19] They consider this type of carcinoma to be a disease of the central portion of the lung.

The distribution of carcinoma in the bronchial tree is somewhat reminiscent of that in the gastrointestinal tract. Carcinomas occur at points of comparative stasis, where the contained material may remain for some time. In the gastrointestinal tract, these include the cardiac end of the esophagus and the pyloric end of the stomach. Almost none are found in the small intestine. Again the incidence increases at the ileocecal valve, and carcinomas occur with increasing frequency in the large intestine as peristalsis decreases and as the rectum is approached. In this tract, also, one receives the impression that time and concentration are prime factors.

SUMMARY

What information has this series of studies on cigarette smoking, bronchial

carcinoma, and ciliary action yielded? What is fact, and what is reasonable assumption?

These things seem to be *fact:* Much of the visible smoke from ordinary cigarette smoking is deposited in the lower respiratory tract upon and in the mucous blanket, wherever the inspired air flows. Part is dissolved and absorbed, and the rest is carried away with the mucous blanket in the ciliary stream to the esophagus.

The ciliary stream begins in the respiratory bronchioles in a stream-bed that is meters in extent. In the short distance from the respiratory bronchioles to the coryna, it narrows to about 50 mm., which is the circumference of the trachea. Further sharp narrowing occurs where tributary bronchi join, and this narrowing may be extreme where two or more tributary bronchi enter another at the same level.

The volume of mucus flowing over a unit area increases as the stream-bed narrows. This increase is further enhanced by any additional mucus secreted by the glands encountered en route. It is a *probability* that the velocity of flow increases as the stream-bed narrows.

In its course from the respiratory bronchioles to the esophagus, it is *known* that the ciliary stream encounters a number of obstructions, over which or past which it must flow. Among these are the openings of the tributary bronchi, the squamous epithelium of the vocal cords, and squamous islands or other areas of metaplasia that are devoid of cilia. At the vocal cords and at each bronchial opening, the axial progress of flow, in these specimens, ceased and the mucous blanket was torn asunder to flow in two opposite directions about at right angles to the previous flow. It is *certain* that the same thing happens in the living organism at the bronchial openings, and it is a *reasonable assumption* that it occurs in the living organism at the vocal cords.

Several *possibilities* for comparative stasis and prolonged action of contained carcinogenic substances exist in this ciliary stream (time and the concentration factors of Arley and Iversen):

A. Where the mucous blanket divides in the middle of the bronchial lip (septa)
B. In whirlpools that may occur just where the four-way split of the two mucous blankets of joining bronchi occurs—here the chemical action would be favored by stirring
C. Upon squamous islands or areas of metaplasia that are known to occur in many individuals
D. Upon the vocal cords where squamous epithelium is encountered—especially anteriorly, where the mucous blanket must split

The extent of this slowing or comparative stasis is unknown. But should slowing or comparative stasis occur habitually in a smoker at any one of such points, then the conditions of the skin experiments with tar* might be closely simulated: accumulation of tar applied over more or less extended periods to the same spot all day long, day after day, month after month, and year after year, until the supposedly necessary one third to one half of the individual's life-span had passed.

The distribution of squamous cell carcinoma in the respiratory tract *suggests* a relation to the ciliary streaming. These carcinomas are apt to occur among the larger bronchi, where the ciliary stream has been gathered from a wide stream-bed into a narrow one and where obstructions in the form of bronchial openings and squamous islands occur. They do not commonly occur in the trachea where the flow is more uninterrupted but

*Experiments in which carcinoma is produced by means of coal and tobacco tar painted frequently on the skins of experimental animals for one third to one half of their life spans(8,16,17,20,23,24).

do occur again upon the vocal cords where the squamous epithelium acts as an obstruction to flow. These possibilities obtain for any inhaled, slowly acting, carcinogenic substance and are by no means limited to cigarette tar.

These studies have not demonstrated that a causative relation between bronchogenic carcinoma and cigarette smoking exists, nor that the distribution of squamous cell carcinoma is related to ciliary streaming, but the findings are suggestive of both and support other evidence. Neither is it to be supposed that other factors are not involved. Air flow and eddies in the air flow very probably play a role.

I am indebted to the Elliott Packing Company, Duluth, Minnesota, for furnishing the animal specimens used in this study and to the Department of Pathology of St. Luke's Hospital for their cooperation in making autopsy material available, and in particular to Dr. Volker Goldschmidt, pathologist, for his photographic work.

REFERENCES

1. Arley, Niels, and Iversen, Simon: On the mechanism of experimental carcinogenesis. III. Further development of the hit theory of carcinogenesis, Acta path. et microbiol. Scandinav., 30:21-53, 1952.
2. ———:On the mechanism of experimental carcinogenesis. VI. Hit theoretical interpretation of some experiments of Berenblum & Shubik, Acta. path. et microbiol. Scandinav., 31:164-171, 1952.
3. ———: On the mechanism of experimental carcinogenesis. IX. Application of the hit theory to tumors produced by ultraviolet radiation, Acta path. et microbiol. Scandinav., 33:133-150, 1953.
4. Auerbach, Oscar: Changes in bronchial epithelium as determined by step sectioning. Presented at Symposium on Cancer of the Lung at the Third National Cancer Conference, Detroit, Michigan, June 5, 1956 (in press).
5. Auerbach, Oscar, et al.: The anatomical approach to the study of smoking and bronchogenic carcinoma, a preliminary report of forty-one cases, Cancer, 9:76-83 (Jan.-Feb.) 1956.
6. Butenandt, Adolf: Biochemische Untersuchungen zum Problem der Krebsentstehung, Verhandl. deutsch. Gesellsch. inn. Med., Kong., 55:342-364, 1949.
7. Dalhamn, Tore: A method for determination in vivo of the rate of ciliary beat and mucous flow in the trachea, Acta physiol. Scandinav., 33:1-5, 1955.
8. Graham, Evarts A.: Remarks on the aetiology of bronchogenic carcinoma, Lancet, 1:1305-1308 (June 26) 1954.
9. Hilding, A. C.: On cigarette smoking, bronchial carcinoma and ciliary action: III. Accumulation of cigarette tar upon artificially produced deciliated islands in the respiratory epithelium, Ann. Otol., Rhin. & Laryng., 65:116-130 (March) 1956.
10. ———: On cigarette smoking, bronchial carcinoma and ciliary action: I. Smoking habits and measurement of smoke intake, N. England J. Med., 254:775-781 (April 26) 1956.
11. ———: On cigarette smoking, bronchial carcinoma and ciliary action: II. Experimental study on the filtering action of cow's lungs, the deposition of tar in the bronchial tree and removal by ciliary action, N. England J. Med., 254:1155-1160 (June 21) 1956.
12. ———: On cigarette smoking, bronchial carcinoma and ciliary action: IV. Ciliary streaming through the larynx and distribution of laryngeal epithelium, Ann. Otol., Rhin. & Laryng., 65:736-747 (Sept.) 1956.
13. Hilding, A. C., and Hilding, David: The volume of the bronchial tree at various levels and its possible physiologic significance, Ann. Otol., Rhin. & Laryng., 57: 324-342 (June) 1948.
14. Iversen, Simon, and Arley, Niels: On the mechanism of experimental carcinogenesis, Acta path. et microbiol. Scandinav., 27:773-803, 1950.
15. ———: On the mechanism of experimental carcinogenesis. V. Application of the hit theory to virus-induced tumors, Acta. path. et microbiol. Scandinav., 31: 27-45, 1952.
16. Lu-Fu-hua: Über die Erzeugung von Krebs durch Tabakteerpinselung beim Kaninchen, Frankfurt. Ztschr. f. Path., 46:513-522, 1934.

17. ———: Über die Erzeugung von Krebs durch Tabakteerpinselung bei Kaninschen. II. Über das Solitarauftrelen einzelner Tumoren auf einer diffus gereizten Körperstelle, Frankfurt. Ztschr. f. Path., 47: 52-62, 1934.
18. Miller, William Snow: The Lung, Springfield, Illinois, Charles C Thomas Co., 1937, p. 20.
19. Moersch, Herman J., and McDonald, John R.: The significance of cell types in bronchogenic carcinoma, Dis. of Chest, 23:621-633 (June) 1953.
20. Roffo, A. H.: Carcinoma desarrollado a los tres años en un conejo fumador, Bol. Inst. de med. exper. para el estud. y trat. d. cáncer, 8:545-573 (Dec.) 1931.
21. Ryan, Robert F., and McDonald, John R.: Bronchogenic carcinoma with in situ carcinoma in the opposite lung: report of five cases, Proc. Staff Meet., Mayo Clin., 31:478-485 (Aug. 22) 1956.
22. Satterlee, Henry S.: The problem of arsenic in American cigarette tobacco, N. England J. Med., 254:1149-1154 (June 21) 1956.
23. Wynder, Ernest L.; Graham, Evarts A., and Croninger, Adele B.: Experimental production of carcinoma with cigarette tar, Cancer Research, 13:855-864 (Dec.) 1953.
24. Yamagiwa, Katsusaburo, and Ichikawa, Koichi: Experimental study of the pathogenesis of carcinoma, J. Cancer Research, 3:1-29 (Jan.) 1918.

DISCUSSION

THOMAS C. GALLOWAY, M.D., Evanston, Ill.: I do not wish to prolong the discussion, but I should like to add one other consideration. It is curious that nearly all of the emphasis has been placed upon tars as the carcinogen in the use of tobacco.

My interest was aroused by a patient who had daily, for 20 years, placed tobacco from cigar wrappers on the left side of her tongue and held it there for hours, almost with the precision of a laboratory experiment. She had an area of leukoplakia, 3 by 4 centimeters, and arising from that she had two epidermoid carcinomas, each about one centimeter wide. Tobacco tars are apparently not formed under a temperature of less than 500° C. and so could not have been responsible in this case.

Some facts strongly suggest that arsenic might be important rather than tars in carcinoma associated with the use of tobacco: (1) lead arsenic is the usual pesticide used by the American tobacco growers; (2) carcinoma occurs after chewing tobacco and snuff, especially when the base is American tobacco on which lead arsenic is used as a pesticide; (3) betel nut cancer occurs only when tobacco is combined in the mixture; (4) localization of arsenic in certain tissues, including epithelium, has been reported in the recent fine paper by Rutledge; (5) relative freedom from arsenical dermatoses is noted when arsenic-free tobacco is used. I know of two places in this country where the growers for their own use do not use lead arsenic but manually remove the insects. The fact that the calculated latent carcinogenic period of arsenic fits for tobacco cancer suggests that the arsenic may be, of itself or in combination with tars, the possible important factor.

I think that this will probably be proved one way or the other fairly soon. A smoking experiment directly using tobacco smoke with arsenic, and using tobacco smoke without arsenic as a control, might help to prove this contention. We might revise some of our thinking about tobacco carcinoma. Possibly replacing arsenicals with some other insecticides might permit those addicted to the weed to take up tobacco smoking again without apprehension.

Symposium: Allergy of the Ear

THE DIAGNOSIS OF ALLERGY

HERBERT J. RINKEL, M.D.
KANSAS CITY, MISSOURI

BY INVITATION

IN the diagnosis of the potentially allergic individual two separate problems must be solved. First, is this an allergic individual, and if so, are the symptoms actually due to an allergen? Second, if the manifestations are allergic in nature, what are the specific etiologic factors? If at all possible, the first part of the diagnostic problem should be completed to the extent of establishing that the patient is allergic before one subjects him to routine specific allergic diagnosis. When specific sensitization is studied, not only should one prove that sensitivity exists but he must also prove that allergy is specifically related to the symptoms under consideration.

CRITERIA FOR IDENTIFYING THE ALLERGIC INDIVIDUAL

The first criterion is the family history. This should be limited to the histories of the brothers, sisters, parents, and grandparents. Inquire about the following symptoms and syndromes:

1. Asthma; chronic bronchitis; chronic wheezing; pulmonary expectorations
2. Hay fever; perennial hay fever; "chronic sinus"; "chronic catarrh"
3. Chronic or long recurring headaches; "sick headaches"; "familial headaches"
4. "Chronic stomach trouble"; "chronic dyspepsia"; long-continued nonviolent abdominal symptoms; attacks of diarrhea without apparent cause
5. Skin lesions: eczema in early life; eruptions on exposed parts of the body; urticarial types of lesions

The nasal and abdominal symptoms will appear with greatest frequency in the family history, but one should bear in mind that allergic expressions may show variations in successive generations, although the type of allergy in the child will be that of the parents about 80 per cent of the time.

In taking the history of the patient, these identical symptoms are carefully studied, and the history taking should be repeated after a period of time. Many patients are not aware of the fact that they have a "rabbit's nose" until they are quizzed about it. Many deny any food dyscrasias, but they will later list a number of items which they omit from their diet because those foods disagree with them.

In practically all patients in whom allergy has been proved, there have been nasal and abdominal symptoms characteristic of allergy. Hansel remarked some time ago that the more carefully the history was taken in patients with perennial nasal allergy, the fewer there would be without some form of chronic abdominal symptoms.

Three criteria have been exceptionally valuable in the differential diagnosis:

1. The existence of pruritus, usually of the nose, often of the roof of the mouth and soft palate. It may occur in

Presented at the Sixty-First Annual Session of the American Academy of Ophthalmology and Otolaryngology, October 14-19, 1956, Chicago.

other areas, but it is seldom absent in the presence of specific allergic reactions.

2. Exacerbations of the symptoms in question which last from eighteen to seventy-two hours, occasionally for five days.

3. Development of typical flares during the night, or the presence of such flares upon awakening in the morning.

That these criteria were present in every patient subjected to three or more unsatisfactory surgical explorations for chronic abdominal symptoms is worthy of more than passing comment. They have been present in every case in which our studies have resulted in improvements of hearing.

Finally, if the patient is sure that a certain product initiates the specific symptoms under study, it enhances the possibility that those symptoms have an allergic causation. Again, if therapeutic trial with adequate doses of antiallergic drugs results in temporary abatement of the patient's trouble, the possibility of sensitization is enhanced.

It cannot be stressed too much that the establishment of allergy in the individual is not proof that the clinical entity under study is necessarily due to allergy. It enhances the possibility; it does not clinch the diagnosis. For example, a patient with a number of demonstrable specific allergies may consult you for intermittent deafness; yet, the deafness may bear no relation to any specific allergy.

The physical examination may give helpful and, frequently, almost conclusive evidence of the presence of allergy. Enlarged, boggy, blue-gray turbinates, postnasal mucoid discharge, and pharyngeal bands with or without punctate lymphoid patches on the posterior pharyngeal wall, when present support the presence of allergic reaction. Other supportive findings are multiple musical expiratory rales and eczema of the cubital and popliteal fossae (usually in children only). Pallor, particularly in children, is highly suggestive, and when it becomes accentuated soon after a meal, it is almost indicative of food allergy. If, with these flares, the specific symptoms under consideration are also increased, the probable diagnosis of allergy is definitely enhanced. Finally, eosinophilia of nasal secretions and of the blood stream is strong evidence of the allergic nature of the disease.

THE DIAGNOSIS OF SPECIFIC SENSITIZATION

Sensitization to a specific antigen, as a rule, will have more manifestations than the clinical entity which is of prime importance at the time. For instance, a patient with loss of hearing who also has perennial nasal allergy or asthma will invariably have specific sensitizations which have no relationship to the hearing problem, which is of first importance to the physician and patient.

One can roughly divide the allergens causing specific sensitizations into two categories: ingestants and inhalants. The inhalants are further divided into pollens, dusts, epithelials, mold spores and smuts.

In the diagnosis of food allergy, it is important to emphasize two points. One is that no matter how complete or careful the history, not all the specific foods can be determined by the history alone. The second is that skin testing for foods, regardless of the experience of the tester or the number of extracts used, results in positive reactions in not more than 20 per cent of the provable food allergies. Conversely, positive tests are only associated with demonstrable cause-and-effect reactions in 40 per cent of the cases. This makes it mandatory that if the role of food is to be evaluated, one must be prepared to do more than skin testing.

The study of foods by deliberate individual food trials is the best single meth-

od for diagnosis of a specific food sensitivity. It is slow, but highly accurate when carried out as detailed. If the patient is free of symptoms for a period of five to seven days or can be brought to such a state by skin tests or food trials, then the diagnostic problem can be completed by use of a food diary. Do not attempt to use the diary alone when symptoms are more or less continuous.

In studying the problem of the relation of food sensitivity to deafness, we have had audiograms made by the referring otologists or by a laboratory. These audiograms are made just before, two and a half hours after, and twenty-four hours after, the specific food trials. Since there was no reason to believe that in these cases the time of reaction would differ from that in perennial nasal allergy, it was felt that this would be adequate. In those patients actually helped as a result of food testing, this had been the case.

If a trial diet is to be used which is limited in content to foods which have been individually tested, enough foods should be checked so that the intake is adequate for the restricted period. This time should be at least seven days. Only food used regularly preceding the testing should be used in such a basic diet. Not all food sensitizations are of a single type. Although the physician may find that he is dealing with a primary food allergy, which means that the patient will have a reaction each time the food is used, it is also possible that he may be dealing with concomitant food sensitization, which means that the food will only cause trouble when the patient inhales specific air-borne products. Concomitant ragweed-food allergies are by far the most common. But sensitization to specific foods may also occur concomitantly with a reaction to dust. Other food sensitizations reach clinical importance only in the winter; in other words, when the patient breathes cool or cold air and is chilled below a critical level, the sensitization to certain foods is enhanced. Again, food sensitizations may be cumulative, which means that spaced feedings will not cause symptoms but daily usage will provoke reactions. Finally, approximately 95 per cent of allergies to specific foods will disappear with strict elimination of the foods in question. Therefore, a re-evaluation of the specific food allergens should be made after strict elimination varying from six to eighteen months.

Concomitant with the determination of food sensitization, one should initiate and complete a determination of inhalant sensitizations. This can be done by the method of testing advocated by Hansel[1] and by me[2,3,4] during the past fifteen years. When carried out as directed, the procedure is safe and highly diagnostic. The method is to test with solutions of increasing strength until one finds the weakest solution capable of producing a positive skin reaction. False positive reactions will occur in testing inhalants, but almost without exception an inhalant actually causing symptoms will give a positive reaction in some dilution, if tested at the time when it is actually producing clinical symptoms. Therefore, an evaluation of the patient's contacts after completion of testing will determine which of these products are to be used in treatment. Air-borne products to which the patient is nonreactive out of season should be rechecked in season if there is a recurrence of symptoms.

Therapeutic trial by means of a small series of doses should be carried out with only those antigens to which the patient is exposed. Dosage is not to be determined empirically, but it must be individualized both as to quantity and interval of the dose. When there is a specific relationship between some air-borne product and the symptomatology in question, short periods of relief should be obtained with carefully graded doses.

These should increase with the increment of the dose; however, when the optimum range is exceeded, the symptoms should recur promptly (from fifteen minutes to several hours) following the dose. This recurrence may or may not be associated with local redness and swelling at the site of the injection.

Again, relief may be temporarily lost due to changes in the degree of sensitization; therefore, a patient should be checked for possible changes in the degree of specific sensitization.

Before any inhalant is designated as the specific one which has caused the patient's symptoms, it should be demonstrated that proper doses of the specific antigen will produce relief; that symptoms recur when the dose wears off; and that relief can again be established with proper treatment doses. It is implied that all dietary factors are controlled during this time.

In those instances in which the physician suspects an allergy to a fungus as an etiologic factor in external otitis, the diagnostic procedures differ in several respects, but two distinct procedures must be included.

In determining the degree of sensitization, the end point of reaction will be reached when a given dilution in the series produces any whealing with erythema—usually a 6 or 7 mm. wheal, with from 15 to 20 mm. of erythema. Treatment is started with the third dilution below the one which produced the end point of reaction, i.e., if solution no. 5 produces the end point, treatment is started with 0.10 cc. of the no. 8 dilution. (These are 1-to-5 dilutions.) The second necessary procedure is to evaluate the possibility of concomitant sensitization to the fungus and to yeast-containing foods. This, therefore, requires the complete elimination of all foods containing yeast for a period of four days and deliberate ingestive trial at noon on the fifth day. Our experiences show that this latter procedure is one of the most important in the handling of allergy due to fungus.

RESUME

In résumé, then, one should evaluate the presence of allergic syndromes in the direct antecedents and in the brothers and the sisters of the patient. He should elicit signs and symptoms of allergy of the more familiar types in this patient. Finally, he should determine whether the symptoms elicited are those usually experienced with allergic reactions. He may be helped in this procedure with the presence of the criteria of allergy, but the demonstration of specific cause and effect must be made in order to complete the diagnosis.

The establishment of foods as a cause of symptoms lies in the ability to reproduce such symptoms at will with specific articles in the diet. In the case of inhalants, besides the positive skin reaction, therapeutic trial dosage should give periods of relief which increase as the dose is increased; but which will result in a recurrence of symptoms when it is increased beyond the optimum range. The physician who states that allergy is the cause of specific symptoms should bear in mind that he must be prepared to reproduce these symptoms at will under correct conditions of testing. This is always possible in the presence of a specific allergic syndrome.

REFERENCES

1. Hansel, French K.: Coseasonal intracutaneous treatment of hay fever, J. Allergy, 12:457-469 (July) 1941.
2. Rinkel, Herbert J.: Inhalant allergy, I. The whealing response of the skin to serial dilution testing, Ann. Allergy, 7:625-630 (Sept.-Oct.) 1949.
3. ———: Inhalant allergy, II. Factors modifying the whealing response of the skin, Ann. Allergy, 7:631-638 (Sept.-Oct.) 1949.
4. ———: Inhalant allergy, III. The coseasonal application of serial dilution testing (titration), Ann. Allergy, 7:639-645 (Sept.-Oct.) 1949.

Symposium: Allergy of the Ear

THE EXTERNAL EAR

EDLEY H. JONES, M.D.
VICKSBURG, MISSISSIPPI

THE external ear is entirely covered by skin; obviously, therefore, allergy of the external ear is dermatologic allergy. A review of dermatologic and allergic literature reveals a rather confused terminology, and I think that the best outline, with minor modifications, is that in "Etiologic Classification of Diseases Involving the External Ear" by Senturia and Marcus[8]:

ALLERGIC DERMATITIS

A. Contact Dermatitis
B. Infectious Eczematoid Dermatitis
C. Drug Eruptions (Dermatitis Medicamentosa)
D. Atopic Dermatitis
E. Urticarial and Edematous Lesions
F. Physical Allergy

The last two subheads are included only for thoroughness; so far as personal experience and a review of the literature are concerned, the external ear is affected by these two conditions only incidentally in connection with a more extensive involvement.

While "it ought to be stated as a premise that a hypersensitive state developed without previous contact to specific antigen is not allergy,"[1] our conception of these conditions will be clarified if we keep in mind that "contact dermatitis and eczema are one thing; urticaria, hay fever and all such immediate wheal-reacting allergies are another."[2] However, they may co-exist in the same patient and at the same time.

Contact dermatitis of the external ear is truly a dermatologic condition, but, quite understandably, it is more often seen by the otologist. It must be differentiated from lesions caused by external irritants. Etiologically, these lesions fall into the following classification:

1. Metals
   Chrome, nickel, silver, gold, etc.
2. Chemicals (other than drugs)
   Cosmetics, nail polishes, soaps, detergents, hair dressings, dyes, plastics, resins, gums, hydrocarbons, aldehydes, acids, alkalies, etc.
3. Drugs
   Sulfonamides, antibiotics, mercurials, coal tar derivatives, hormones, etc.
4. Miscellaneous
   Plants (dermatitis venenata), animal epithelials, rubber, leather, etc.

It is characteristic of contact dermatitis that the lesions itch, burn or sting; and this is an important diagnostic point. The lesions are erythematous and edematous at first, then become vesicular and heal by desquamation. With continued contact, however, vesiculation spreads; and with secondary infection, it may appear pustular with crusted eruptions. The degree of involvement varies with the potency of the antigen, the duration of contact, and the suscepti-

From the Department of Otolaryngology, University of Mississippi Medical School.

Presented at the Sixty-First Annual Session of the American Academy of Ophthalmology and Otolaryngology, Oct. 14-19, 1956, Chicago.

bility of the patient. In the majority of cases, the pruritis is so intense that scratching causes rapid involvement of the surrounding areas and increases the severity of the lesions.

An allergy to metals may be evidenced by women who wear earrings. The lesions usually originate on the lobule but spread rapidly to the postauricular area and concha, and they may involve the canal. Allergic lesions due to the metal bows of spectacles usually originate in the postauricular area. Lesions due to chemicals vary in the site of original involvement with the etiologic agent. Dermatitis due to nail polish usually originates in the superior portion of the concha and antihelix; that due to shampoo or hair dye, on the superior postauricular area. Fur neckpieces and collars may cause dermatitis of the lobule and of the postauricular area. If the canal is primarily involved, drugs (ear drops) should be suspected.

While the chemical group includes ingredients used in many drugs, I have made a separate classification which includes the antibiotics, the hormones, and the sulfonamides, for this group is of greatest interest to the otologist. In these days of widespread advertising, over-the-counter dispensing by pharmacists, and the pleased patient who passes along the "ear drops" prescribed for him, the majority of patients suffering with contact dermatitis of the external ear have employed self-medication before consulting the otologist. In such cases the history is most important. Often the patient reports that the symptoms have progressed rapidly with home treatment, with more pruritis and discomfort; such a history is quite indicative of an allergy to a drug. In the early stages the lesions show definite erythema and edema; after careful cleansing the brawny, edematous, erythematous appearance is almost diagnostic. After vesiculation, the lesions heal by desquamation and may appear lichenified.

This group of patients is of further interest in that the preparations employed or prescribed by the otologist in the treatment of an external otitis may—to the chagrin of the otologist—initiate a superimposed contact dermatitis with increasing discomfort. For example, Fowler and Freeman[6] reported that 22 per cent of cases treated with one sulfonamide preparation showed "eczematoid skin sensitivities," and that 27 per cent of cases treated with another sulfonamide preparation showed a similar reaction. Contact drug allergy is often a factor and should always be suspected in patients who have a chronic discharge following radical mastoid or fenestration surgery.

The clinical picture is frequently complicated by a superimposed infection, caused by the patient's scratching the lesions, and resulting in infectious eczematoid dermatitis. Indeed, any form of allergic dermatitis may be so complicated.

In the acute stages of dermatitis due to an allergy to drugs, considerable relief is afforded by wet packs of Burow's or Domeboro's solution, followed by the application of a soothing cream such as Acid Mantle®, or Panthoderm®. Quotane® lotion is often valuable in relieving pruritis. Preparations containing cortisone or its analogues are effective in some patients but not in others; I prefer to administer prednisolone orally. I do not recommend cream or ointments containing antihistamines, but have found antihistamines administered orally to be of some value in relieving pruritis, particularly those with a sedative effect. These antihistamines are definitely to be preferred to barbiturates for sedation; with barbituate sedation the patient continues to scratch, even though apparently sound asleep.

It is important in treatment to keep everything except prescribed medications from touching the involved areas —*particularly, the patient's hands.* It must be kept in mind not only that scratching makes these lesions worse but that the fingers touch many, many substances. Some of these substances, though not ordinarily irritating to the skin of the normal ear, will irritate an inflamed lesion and contribute to the continuation and severity of the inflammation.

In general, dermatitis medicamentosa (eruptions following the ingestion, injection, or inhalation of drugs) like dermatitis venenata, is of little interest to the otologist; the ear is involved only as a part of a generalized process. There is, however, one phase which is of interest in this discussion. For many years dermatologists have recognized "fixed drug eruptions," circumscribed skin lesions that persistently recur at the same site whenever the exciting drug is ingested. Allergists are familiar with this condition which, as related by Vaughan,[10] was recognized shortly after antipyrine came into use in 1885 and was clearly described and given the present name by Brocq in 1894.

There is a classical laboratory experiment known as the Shwartzman phenomenon which demonstrates fixed allergic response in a localized area. A minute quantity of typhoid or other culture filtrate is injected into the skin of the ear of a rabbit; twenty-four hours later a large quantity is injected intravenously; hemorrhagic necrotic areas appear at the site of the skin injection in five to six hours. (This procedure was utilized by Fowler[5] in his recent studies on hypersensitization of tissue in infections and allergic reactions.)

If patients can have fixed drug eruptions, and if localized areas of the skin of laboratory animals can be sensitized, it is logical to conclude that patients can also have localized, sensitized skin areas with a fixed allergic response. A search of the literature reveals that this is true.

Cooke[3] in 1947 described a case of an itching eruption on the right eyelids only, which was proved to be due to allergic sensitivity to tomato. On three separate trials, the lesion reappeared on the third day after eating tomato. Oddly enough, the patient did not react to intradermal testing on the arm or to patch testing on the trunk or extremities, but nightly application of tomato juice to the lids of both eyes produced the typical lesion, on the right eye only, at the end of the second day. Henry[7] reports a case of a young white girl with localized edema of the left wrist accompanied by profuse perspiration of the affected area, but with no other involvement. It proved to be due to a sensitivity to milk.

It obviously follows that such a condition may involve the skin of the external ear. Admittedly, such cases are rare but they do occur. Derlacki[4] described a case of alternating crusty and weeping eczema of the left external ear canal and postauricular region, which proved to be due to allergy to pork; and two cases of persistent discharge from postfenestration cavities, one due to an allergic reaction to dust, and the other to a sensitivity to cottonseed oil. In the second case, an allergy to dust was suspected because of a recurring dermatitis on the hands during winter, but in the two other cases only the ear was involved.

Henry[7] has reported a case of furunculosis of the external canal due to pork. In this case, the patient had an atopic dermatitis of the external ear canal, with pruritis. Scratching of the ear canal initiated secondary infection with furuncle formation. The condition recurred on three separate trials with pork.

To these cases, I can add another. Miss A. K., a white female known to have a history of allergy, at the age of 5 ate a very large quantity of fresh strawberries. Within a few hours her ears began to swell, and within twenty-four hours both external auditory canals were almost entirely occluded, the postauricular areas were so swollen that the ears stood out from the head, and the skin over the mastoid showed well-defined erythema. She also had an accompanying acute allergic rhinitis. The severe phase subsided after three days, with complete relief after seven days. At a later date, this patient ate a smaller quantity of strawberries with a similar, though less severe, reaction. Because of the child's love of strawberries, this episode was repeated yearly, with similar reactions, until she was 10 years old. Since then she has not had auricular symptoms, but as recently as this spring (she is now 16) an attack of allergic rhinitis was precipitated when she ate two fresh strawberries. She had a two plus reaction to intradermal testing with strawberries, and this was confirmed by passive transfer.

While the diagnosis may be indicated by the history, as in the above case, more often it is made as the result of painstaking studies—a detailed history, studies of smears of discharge, differential white blood counts, skin tests (patch, scratch and intradermal), elimination diets, and trial diets. It should always be confirmed by the therapeutic test.

Additional evidence that allergy must be considered as a factor in acute diffuse external otitis can be found in Sophian and Senturia's report of biopsies in five cases.[9] They commented that the exudate in each case was notable for its high content of eosinophils, and on the "possible importance of altered tissue reactivity as a contributing factor in the etiology of acute diffuse external otitis." It seems remarkable, when only five biopsies were made, presumably of tissue from unselected patients, that all five should indicate the presence of an allergic condition; and it is regrettable that the history, the previous treatment, blood counts, and the clinical course of each of these patients were not discussed as thoroughly as the pathologic changes evidenced by the biopsy.

During the past summer I made biopsies of tissue from three cases of acute diffuse external otitis, one of which was complicated with furunculosis. Time will not permit detailed presentation but, in brief, the pertinent findings were as follows:

Case 1. A 45-year-old white male had a family and personal history of allergy and of recurrent attacks of external otitis. He had received 800,000 units of Pronapen® the previous day. The white blood count was 16,700, with only 3 per cent eosinophils. The biopsy revealed round cell infiltration, with clumps of neutrophils in the epidermis and only a rare eosinophil.

Case 2 was that of a 15-year-old Negro boy with no previous treatment. His history gave no evidence of a background of allergy. The white blood count was 18,300, and no eosinophils were found in a count of 100 cells. The microscopic picture was that of an acute inflammatory process with neutrophilic infiltration and rare eosinophils.

Case 3 was one of furuncle formation. A 12-year-old white boy with no record of allergy in his family history, but with a record of dermatitis in his personal history, had had previous attacks of otitis media, but not of external otitis. He had had no previous treatment. The white blood count was 7,700, with 9 per cent eosinophils. The microscopic picture was that of a very acute inflammatory process with polymorphonuclear infiltration, 15 to 20 per cent eosinophils.

In these cases, allergy obviously was not a factor in the first two, though one had an allergic background; it definitely was a factor in the third.

It is obvious that allergic conditions of the external ear will comprise only a small percentage of the average otologist's practice, but their successful management requires correct diagnosis and proper treatment. We cannot draw too many conclusions from these few cases, but if otologists will suspect allergy in "therapy-resistant" and recurrent cases, and if they will carefully work them up and report them, we may find that allergy of the external ear is not so rare —just rarely diagnosed.

Appreciation is expressed to Dr. Tom Norman and the Department of Pathology of the University of Mississippi Medical School for their cooperation in making these studies.

REFERENCES

1. Allen, Arthur Charles: The Skin, a Clinicopathologic Treatise, St. Louis, C. V. Mosby Co., 1954, p. 206.
2. Andrews, George Clinton: Diseases of the Skin, ed. 4, Philadelphia, W. B. Saunders Co., 1954, p. 103.
3. Cooke, Robert A., et al.: Allergy in Theory and Practice, Philadelphia, W. B. Saunders Co., 1947, p. 244.
4. Derlacki, Eugene L.: Aural manifestations of allergy, Ann. Otol., Rhin. & Laryng., 61:179-189 (March) 1952.
5. Fowler, Edmund P., Jr.: Hypersensitization of tissue to infections and allergic reactions, Ann. Otol., Rhin. & Laryng., 65: 15-28 (March) 1956.
6. Fowler, Edmund P., Jr., and Freeman, Richard: Therapeutic results. In Symposium: Medical Management of Chronic Otic Skin Infections, Tr. Am. Acad. Ophth., 58:685-691 (Sept.-Oct.) 1954.
7. Henry, John P.: Personal communication.
8. Senturia, Ben H., and Marcus, Morris D.: Etiologic classification of diseases involving the external ear, Ann. Otol., Rhin. & Laryng., 61:18-32 (March) 1952.
9. Sophian, L. H., and Senturia, Ben H.: The pathology of acute diffuse external otitis, Ann. Otol., Rhin. & Laryng., 64: 300-318 (March) 1955.
10. Vaughan, Warren T.: Practice of Allergy, St. Louis, C. V. Mosby Co., 1939, p. 816.

Symposium: Allergy of the Ear

THE MIDDLE EAR

EUGENE L. DERLACKI, M.D.
CHICAGO, ILLINOIS

IT is our premise that allergic involvement of the middle ear is part of a generalized allergic reaction of respiratory epithelium, with selective emphasis upon the mucous membranes of the eustachian tube and of the tympanic cavity with its mastoid extensions. This premise is based upon clinical observations and studies and not, unfortunately, upon the much sounder evidence which histopathologic study of middle ear and tubal epithelium in presumably allergic disorders of these structures would provide.

The characteristic histopathologic changes of tissue edema with eosinophilic infiltration and of seromucinous gland and goblet-cell hyperactivity which occur in acute and chronic allergic rhinitis and sinusitis have been thoroughly described by Semenov,[6] Hansel,[4] and others. These changes in the individual structures of the mucous membrane have been documented and correlated with the clinical manifestations of acute and chronic nasal allergy. Similarly, it has been possible to correlate clinical response to allergic therapy with observable reversible pathologic changes in nasal and sinus mucosa. Frequent cytologic examinations of the nasal secretions, as advocated by Hansel over the years, has established a valuable objective test of the presence of active nasal allergy and has provided a means for following the clinical course of such allergy when complicated by infections.

Presented at the Sixty-First Annual Session of the American Academy of Ophthalmology and Otolaryngology, October 14-19, 1956, Chicago.

In comparison to the nose, the less accessible anatomy of the eustachian tube and middle ear makes careful and direct observation of mucosal changes in allergic or infectious inflammation more difficult. Mucosal biopsies are similarly restricted, particularly in private practice. Thus relatively few exhaustive histopathologic studies have been performed and recorded in presumably allergic conditions of the middle ear. Koch,[5] in his monograph on chronic allergic otitis media, presented a most careful study of tissue and secretion eosinophilia. However, this condition seems to be only one of several manifestations of allergic middle ear disease, and also the only one in which the mucosa of the middle ear might be relatively available for specimen taking and histopathologic study.

We agree with other authors that aural cytologic studies have not been found consistently helpful in supporting an allergic diagnosis. This may be a partial reflection, particularly in chronic secretory otitis media, of a variable allergic pathogenesis.

The difficulty in direct visualization of mucosal tissue changes, the rarely possible histopathologic study of material taken for biopsy, and the unreliability of aural cytology all make a diagnosis of allergic middle ear disease less tenable than most other allergic diagnoses in respiratory diseases. In attempting to establish a diagnosis of middle ear allergy, great reliance must be placed upon (1) the history which includes any

evidence of allergic family background, the course of the ear symptoms, and usually a failure to respond to other forms of therapy; (2) the presence of a coexisting chronic nasal or bronchial allergy and often allergic gastrointestinal or skin disease, and (3) the successful therapeutic test to establish specific sensitization: the relief of symptoms by removal of a substance or by treatment with an extract of a substance, and the recurrence of symptoms upon re-exposure to the substance or upon stopping treatment.

Middle ear allergy is responsible for the majority of the cases of chronic secretory otitis media seen in our practice, including some cases of chronic hemotympanum, and for many of the cases of frequently recurrent acute otitis media and of chronic suppurative otitis media with a benign central perforation. In all three conditions the site of allergic reaction can be the same, with the clinical disease entity being influenced or determined by infection.

In chronic secretory otitis media, transient infection of the upper respiratory tract may be the trigger in producing a state of allergic imbalance in the tubal and middle ear mucosa. This state can be maintained indefinitely until an important specific allergic factor is changed to restore allergic balance.

In recurrent acute otitis media, acute respiratory infection affects an upper respiratory epithelium, including the tubal and middle ear mucosa, which is already in a state of allergic inflammation of variable degree. The infectious inflammatory process then becomes the predominant disease of the mucosa of this region.

In chronic allergic suppurative otitis media with a benign central perforation, an acute necrotizing infection of the middle ear either preceded or occurred intercurrently with an allergic involvement of the tubal and middle ear mucosa. The prolongation of secretion thereafter can be due primarily to allergic causes or to allergy plus a superimposed superficial mucosal infection. The author[2] has previously described the clinical picture in these cases, listing the following characteristics: (1) a profuse, thin mucoid or thicker gelatinous secretion containing a varying number of eosinophils; (2) a middle ear mucosa often similar to allergic nasal mucosa both in appearance and in tissue eosinophilia; (3) therapy-resistant; (4) occurrence in allergic individuals with other allergic manifestations, most commonly allergic rhinitis; and (5) likely response to allergic management.

The histology of the upper respiratory tract, eustachian tube and middle ear is an important consideration in the concept of the histopathologic changes which can occur to produce a varying degree of tubal occlusion and secretory otitis media. The respiratory membrane of the nose (similar to that of the trachea and bronchi), the nasopharynx, the adenoid structures and the eustachian tube is capped by cilia. Between the columnar cells, and probably identical with them, are the mucin-containing goblet cells, which are one source of mucus. In the subepithelium, or tunica propria, are the seromucinous glands, which predominate in certain portions of the respiratory tract and are the other source of the mucous coating of the epithelium. Certain irritating stimuli increase the production of mucus not only from the seromucinous glands but from the more active and more numerous goblet cells as well.

In its normal state, the epithelial lining of the middle ear consists of simple nonciliated cuboidal cells with relatively little submucosal connective tissue. However, according to Eggston and Wolff,[3] this epithelium has an inherent

capacity for changes, under apparently slight stimulus, which produce a lining membrane not unlike respiratory epithelium in appearance and behavior.

A number of writers have postulated in the past a variable involvement of the upper respiratory tract, the eustachian tube and the middle ear, and I feel that this is a reasonable hypothesis. We see many cases of seasonal and perennial respiratory allergy in which the principal allergic inflammation involves the nasal mucosa, with little or no apparent involvement of the tracheobronchial tree, and vice versa, so why should there not also be a selective greater involvement of the respiratory epithelium of the eustachian tube or of the metaplastic respiratory-like mucosa of the middle ear? Many patients with eustachian tube occlusion and/or secretory otitis media also have chronic nasal allergy, which is in keeping with the finding in allergic individuals that multiple clinical manifestations of allergy are the rule rather than the exception.

Tubal occlusion and secretory otitis media have been found to have a variable audiometric picture, which, I feel, reflects the pathogenic mechanism in each case and also may lead to a more logical therapeutic approach. Secretory otitis media with the middle ear completely filled, or nearly so, with fluid produced either a relatively flat or downward-sloping (high tones depressed) air conduction audiogram. In some of the downward-sloping audiograms, the low tones can be at or near normal level. In contrast, the cases of eustachian tube occlusion with no fluid or with only a barely perceptible fluid level along the lower drum margin usually show an upward-sloping audiogram with emphasis upon the low-tone loss. To us this is further clinical confirmation of Campbell's interesting and informative paper in 1949, which brought to the attention of American otologists the "differential diagnostic implications of the portions of the (impedance) formula which have to do with stiffness and mass."[1]

Occlusion of the eustachian tube is due chiefly to the inflammatory changes in the respiratory epithelium and adenoid lymphoid structures of the nasopharynx and in the tubal epithelium. The inflammation may be infectious or allergic in nature. Whether the tubal occlusion is complicated by serous fluid in the middle ear depends somewhat upon the degree and the duration of the occlusion. As stated previously, a tubal occlusion depresses the low tones, causing an upward-sloping air conduction audiogram through "the splinting effect of unequal pressure on the two sides of the tympanic membrane" causing an "increase in the stiffness of elements of the conduction system."[1] When a complicating serous effusion occurs in the middle ear (the mechanism of this effusion has been described by many writers), the audiogram is flattened or humped because the "mass of elements of the conduction system" imposes an additive high-tone depression (fig.1). In a child whose nasopharyngeal examination reveals a large adenoid or adenoid remnant which may appear to be producing a mechanical obstruction by its very size, it may be very difficult to evaluate whether this is the sole cause of the tubal dysfunction or whether there is the additional factor of occlusion from inflammatory swelling of the tubal mucosa. I feel that the latter cause may often be the more important one in producing the obstruction to normal ventilation of the middle ear. The clinical examination in a case of tubal obstruction with secretory otitis media reveals a retracted drum membrane with fluid in the middle ear, and in long-standing or frequently recurrent cases there may be considerable attic retraction.

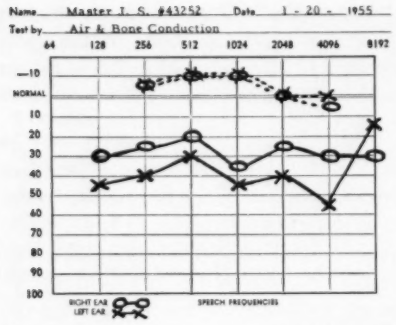


FIG. 1—Bilateral secretory otitis media prior to treatment.

There is a considerable number of cases in which a secretory otitis media produces a downward-sloping curve in the audiogram, with depression of the high tones and near normal hearing for the lower frequencies (fig. 2). The otoscopic picture here again reveals fluid in the middle ear, but there is absence of retraction of the pars tensa or flaccida; in fact, the pars tensa may even be bulging. Both the audiogram and the otoscopic picture speak for an increase of the mass of elements of the conduction system by fluid in the middle ear

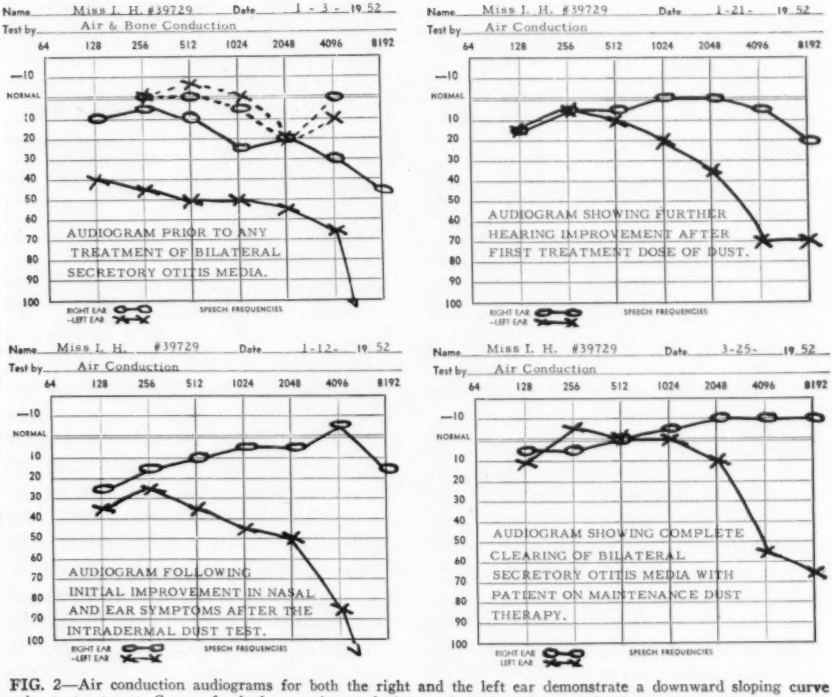

Name Miss I. H. #39729 Date 1 - 3 - 19 52
Test by Air & Bone Conduction
AUDIOGRAM PRIOR TO ANY TREATMENT OF BILATERAL SECRETORY OTITIS MEDIA.
Name Miss I. H. #39729 Date 1-21- 19 52
Test by Air Conduction
AUDIOGRAM SHOWING FURTHER HEARING IMPROVEMENT AFTER FIRST TREATMENT DOSE OF DUST.
Name Miss I. H. #39729 Date 1-12- 19 52
Test by Air Conduction
AUDIOGRAM FOLLOWING INITIAL IMPROVEMENT IN NASAL AND EAR SYMPTOMS AFTER THE INTRADERMAL DUST TEST.
Name Miss I. H. #39729 Date 3-25- 19 52
Test by Air Conduction
AUDIOGRAM SHOWING COMPLETE CLEARING OF BILATERAL SECRETORY OTITIS MEDIA WITH PATIENT ON MAINTENANCE DUST THERAPY.
64 128 256 512 1024 2048 4096 8192
NORMAL
RIGHT EAR
LEFT EAR
SPEECH FREQUENCIES

FIG. 2—Air conduction audiograms for both the right and the left ear demonstrate a downward sloping curve prior to treatment. Curves for both ears change during work-up for allergy and subsequent treatment.

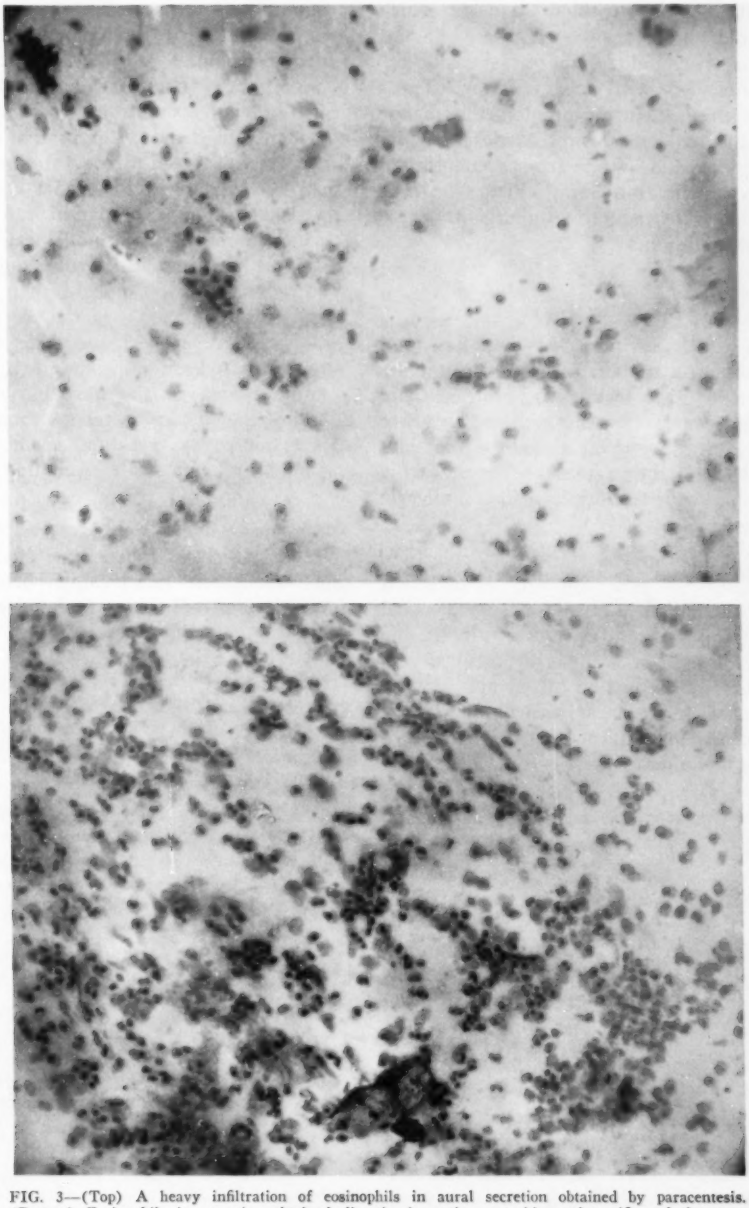


FIG. 3—(Top) A heavy infiltration of eosinophils in aural secretion obtained by paracentesis. (Bottom) Eosinophils in secretion obtained directly from the eustachian tube orifice of the same patient.

with little or no tubal occlusion which would increase the stiffness factor. Moreover, politzerization is easily accomplished with low pressure. These cases reflect, in my opinion, the change in the middle ear mucosa described by Eggston and Wolff[3] from a cuboidal to a columnar epithelium with goblet cells which is reacting to an allergic or vasomotor stimulus.

SUMMARY

The following characteristics and findings in certain cases of chronic secretory otitis media, including chronic hemotympanum, chronic suppurative otitis media with central perforation, and frequently recurrent acute otitis media, give evidence of an allergic causation:

1. "Therapy-resistant," particularly to treatment aimed primarily at infection in the nose, sinuses, nasopharyngeal lymphoid structures, and locally in the middle ear; as well as to surgical and radiologic reduction of lymphoid and mucosal hyperplasia; and finally, to the repeated mechanical evacuation of middle ear fluid.

2. Occurrence in an individual with a family background of allergy who manifests prior or concomitant respiratory allergy as well as possible allergic gastrointestinal and skin disease. When the middle ear symptoms fluctuate or recur coincidentally with the recognized respiratory, gastrointestinal, or skin allergies, then an allergic origin for the middle ear disease is readily acceptable.

3. Demonstrable histopathologic changes characteristic of allergy:

a. Tissue eosinophilia in biopsy specimen from middle ear mucosa in chronic suppurative otitis media. This change is theoretically, but not practically, demonstrable.

b. Secretion eosinophilia is an unreliable finding, but it is strong presumptive evidence in chronic suppurative otitis media with a central perforation. In chronic secretory otitis media, eosinophils could be expected in cases in which a metaplastic middle ear mucosa is reacting allergically and the secretion is more mucoid than thin and watery (fig. 3). If the secretion is transudative due to negative intratympanic pressure produced by allergic edema of the nasopharyngeal end of the eustachian tube without direct middle ear reaction, eosinophils would not be an expected finding.

4. A response in the middle ear symptoms to allergic workup and management which establishes an etiologic cause-and-effect relationship between the symptoms and a specific inhalant or ingestant.

REFERENCES

1. Campbell, Paul A.: The importance of impedance formula in the interpretation of audiograms, Tr. Am. Acad. Ophth., 54: 245-252 (Jan.-Feb.) 1950.
2. Derlacki, Eugene L.: Aural manifestations of allergy, Ann. Otol., Rhin. & Laryng., 61:179-188 (March) 1952.
3. Eggston, Andrew A., and Wolff, Dorothy: Histopathology of the Ear, Nose and Throat, ed. 1, Baltimore, Williams & Wilkins, 1947.
4. Hansel, French K.: Clinical Allergy, ed. 1, St. Louis, C. V. Mosby, 1953.
5. Koch, H.: Allergical investigations of chronic otitis, Acta oto-laryng., 62 (supp.): 1-201, 1947.
6. Semenov, Herman: The pathology of the nose and paranasal sinuses in relation to allergy, Tr. Am. Acad. Ophth., 56:121-170 (March-April) 1952.

THE INNER EAR

RAYMOND E. JORDAN, M.D.
PITTSBURGH, PENNSYLVANIA

THE majority of presentations on allergy of the inner ear discuss Ménière's disease as an example of this phenomenon. This is not unusual, since in this disease the three major symptoms which the inner ear is capable of producing are manifested. These symptoms are vertigo, tinnitus and deafness. Since, however, it is not possible to make a diagnosis of Ménière's disease without qualifying the above-mentioned triad, the characteristics of the disease will be discussed briefly. In true Ménière's disease, the vertigo is intermittent in character and severe in nature. Usually there is freedom from vertiginous symptoms between attacks. The tinnitus is usually a low-pitched roar. The hearing fluctuates, especially early in the disease, and the involved ear presents distortion of sounds, or diplacusis dysharmonica, and often sensitivity to loud sounds, or the phenomena of recruitment. As Day[1] has shown, the cochlear symptoms may appear first, followed later by vertigo in about 48 per cent of the cases.

Since the work of Hallpike and Cairns[2] and Hallpike and Wright,[3] the pathologic basis of Ménière's disease is believed to be an increase in endolymphatic fluid, a fact which gave rise to the term coined by Williams,[5] "endolymphatic hydrops." The origin of this increased fluid has not been clearly defined. The characteristic intermittency of the symptoms of Ménière's disease and the pathologic findings of increased fluid or edema suggest that this disease is allergic in nature. This view is shared by a number of writers, who have reported cases of Ménière's disease in which attacks were precipitated by specific antigens. Hansel[4] reports twelve or more such articles in his recent book, "Clinical Allergy." Williams,[5] in his book on Ménière's disease, classified the disease as belonging in the allergic category. He believes, however, that it is more accurately classified as a physical allergy or as an autonomic dysfunction rather than as an antigen-antibody reaction.

In attempting to justify the assumption that Ménière's disease belongs in the allergic category, a study of 100 consecutive cases was made. These were all private cases followed for a sufficient time to have some statistical value. All cases had the characteristic symptoms described earlier. The management of these cases included an allergic workup, including careful history taking and skin testing. This work was done in our office by Dr. Florence Kline. Treatment consisted of eliminating any foods which produced a positive reaction to skin testing or which were indicated by the history to be suspect. Control of allergies to dust, pollen, and mold was accomplished by desensitization and the weekly or biweekly injections of histamine base. The average starting dose of

Presented at the Sixty-First Annual Session of the American Academy of Ophthalmology and Otolaryngology, Oct. 14-19, 1956, Chicago.

histamine was 1:1,000,000 dilution. The average maintained dose was .1 to .3 cc. of 1:10,000 histamine solution. The starting dose was determined by the intensity of the skin reaction to a 1:1,000 solution of histamine base.

Of interest were some of the points observed in this study of 100 cases. Eighty-eight patients gave a family or personal history of allergy. Seventy-four patients gave a 2 plus, or higher, reaction to one or more foods. Dust was an offending allergen in 87 patients, and 7 patients showed definite pollenosis. Ninety-eight patients responded with a 3 or 4 plus reaction to histamine 1:1,000, and 2 gave a 2 plus reaction. Only 3 patients showed no reaction to dust, food or pollen. Fifteen patients were observed to have an increase in symptoms when exposed to specific antigens, such as food, dust or pollen. The results of the treatment described above were as follows: In 38 patients, vertigo was relieved. Fifty cases were controlled to a point at which the patient could carry on a normal existence with occasional unsteadiness. Twelve patients showed no improvement of vertiginous attacks. Thirty-four patients showed hearing improvement, and in 66 patients the hearing remained the same. In 73 cases, tinnitus was either reduced to a level of tolerance or was completely relieved. In 27 cases, there was no change in the tinnitus.

Some hearing changes were of interest. Frequently, patients under treatment would maintain that their hearing was better even though the audiograms remained the same. Inevitably, in these cases, the improvement was due to improved discrimination rather than to an improved pure tone response. Hearing improvement, for the most part, depended upon how early in the course of the disease the patient was treated. If the patient was treated after one or two attacks of vertigo, hearing improvement was not uncommon. If vertiginous attacks were well established, hearing improvement was unlikely. Similar but more marked hearing response usually was obtained in a group of cases frequently referred to as Ménière's disease without vertigo. These patients had all the clinical symptoms of Ménière's disease except vertigo. In this type of case, restoration of hearing to normal level and reduction of tinnitus are common following the administration of the above-mentioned therapy. The importance of early diagnosis is apparent. No cases without vertigo were included in the above report, however.

In closing, it is not the intent of the writer to intimate that all the aforementioned cases were completely controlled at all times. Relapses did occur, but they were easily traced to a voluntary discontinuance of treatment, laxity in avoiding offending foods or other known allergens, tardiness in starting pollen injections, or emotional upsets. In our practice, this form of therapy has given the best results in Ménière's disease to date. It is my opinion that these results compare favorably with those obtained in any similar group of patients under treatment for allergy.

REFERENCES

1. Day, Kenneth M.: Ménière's disease: present concepts of diagnosis and management, Ann. Otol., Rhin. & Laryng., 59:966-979 (Dec.) 1950.
2. Hallpike, C. S., and Cairns, H.: Observations on the pathology of Ménière's syndrome, Proc. Roy. Soc. Med., 31:1317-1336 (Sept.) 1938; J. Laryng. & Otol., 53: 624-655 (Oct.) 1938.
3. Hallpike, C. S., and Wright, A. J.: On the histological changes in the temporal bones of a case of Ménière's disease, J. Laryng. & Otol., 55:59-66 (Jan.) 1940.
4. Hansel, French K.: Clinical Allergy, ed. 1, St. Louis, C. V. Mosby, 1953.
5. Williams, Henry L.: Ménière's Disease, Springfield, Illinois, Charles C Thomas, 1952.

DISCUSSION

DR. RINKEL: I should like to express my pleasure in appearing with these gentlemen, who have been very conservative in the presentation of the subject this afternoon.

There are a few points which I will cover very briefly.

Do not use ointments in acute vesicular lesions. The localization of the reaction at times may be of extreme importance and has been fully covered, but we have had, this past year, three cases of dermatitis of the face, the neck, and the external ear, due to pollen. They all responded to pollen therapy. In these cases it was necessary to treat with dilutions much weaker than those that are needed to relieve hay fever or asthma. This is also true of all dermatologic lesions due to house dust or molds. As a rule, we start treatment about four dilutions below the one which will produce an endpoint of reaction.

There is, in many instances, a concomitant effect between inhalants and contact responses. As an illustration, a patient with eczema found that it disappeared entirely when he was in New York City. On returning from New York on an air-conditioned train, the eczema recurred when he got to Ohio. It developed overnight when he got west of the Alleghenies. This is not the first time I have heard of such an experience; if it were, I would not relate it to you. The interpretation is that there is a combination of some air-borne product, presumably alternaria, and a specific contact factor—in this case, a wrist watch.

Again I should like to state that no one has really done conclusive work on allergy to bacteria, but allergy to bacteria does exist.

I mentioned not testing foods in lieu of breakfast. I should like to clarify that point. The second thing I learned specifically about food allergy is the fact that a patient might, upon getting up in the morning, eat absolutely compatible foods and have an acute postprandial reaction, provided he had eaten a dinner the night previously which contained food to which he was sensitive. This complication is not so evident if the patient has had breakfast before the tests.

The difficulty of diagnosis was mentioned by Dr. Jordan. This should, of course, be kept in mind, but it should not discourage you. It is a long and difficult problem to prove some of these cases.

Failure to respond to an established therapeutic program should make one consider allergy, but it does not prove its existence.

Those of you who use histamine must be careful of two things. Histamine, even in the minute doses we use, has a tendency to cause amenorrhea in certain patients if it is given just two or three days before the expected menses. Be sure to inquire whether the patient has been under treatment or has been subject to ulcers before using it.

As to an allergic reaction involving the inner ear, I should like to point out that in certain food sensitizations there is a marked tendency to have generalized edema of the tissue. I am sure all of you know about the patient who had been operated upon during the height of an attack of headache. The diagnosis was brain tumor. The tissues were found to be edematous and the cells in the secretions were typical of allergy. Bear this one thought in mind about the role of allergy in various syndromes. If edema of the involved tissue can lead to an increment in symptomatology, allergy may then play a part without its being a specific cause of the symptomatology.

MASS-DISASTER TRACHEOTOME

THOMAS C. GALLOWAY, M.D.
and
JOHN ELSEN, M.D.
BY INVITATION
EVANSTON, ILLINOIS

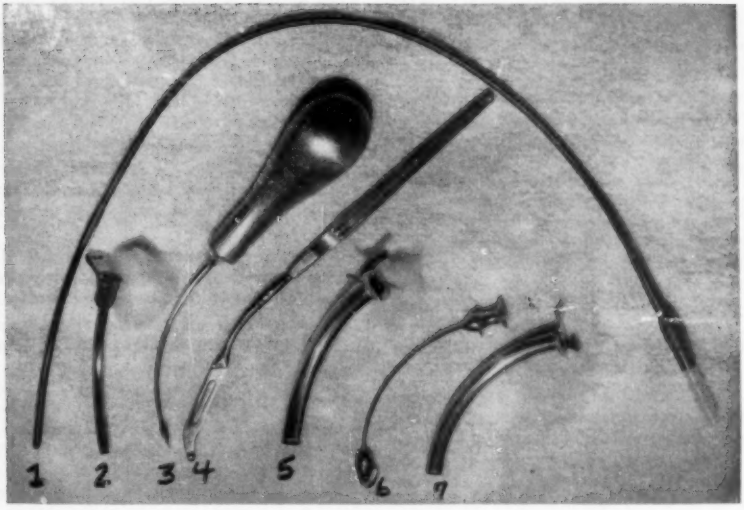


FIG. 1—Tracheotome disassembled. 1. Oxygen catheter. 2. Cannula with slot made wide at top. 3. Trocar. 4. Knife with tip bead to fit slot. 5. Jackson tube with slot. 6. Obturator with inset knife blade. 7. Inner tube.

IF a mass disaster occurs, there is likely to be need for many tracheotomies. Civilian defense and the military services are concerned about preparedness for such an event. The need would be for a simple method usable by relatively untrained personnel and employing equipment easily mass produced.

To that end, we are trying to develop a simple tracheotome. Old trocars were found unsatisfactory. The Sheldon-Riviera instrument used in California is said to have given good service. It is expensive, could not easily be made in quantity, and is now produced only in size 6, which limits its use to adults. The fairly large, straight needle used in this instrument would seem to be dangerous in any hands but those of an expert, especially if the patient were small. We had heard that it used a slot and guide, but we had worked out our own ideas before we saw it. A captured Japanese field instrument is said to be promising. This consists of a knife blade with a collapsible thin tracheal dilator which

Presented as a *New Instrument* at the Sixty-First Annual Session of the American Academy of Ophthalmology and Otolaryngology, Oct. 14-19, 1956, Chicago.

follows the blade inward and a dilating inner tube inserted when the knife blade is withdrawn.

What we present is only provisional and surely can be improved (figs. 1 and 2).

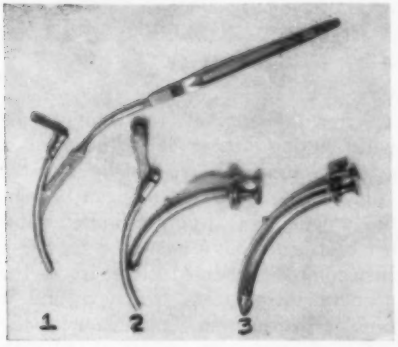


FIG. 2—Tracheotome parts assembled. 1. Knife held in slot by bead. 2. Curved obturator gliding in slot.

Our apparatus seems complicated, but really it is not. It has been made from standard equipment by V. Mueller & Company. It consists of a curved trocar and a cannula with the slot widened at the top and in the anterior concave bend (2 and 3 of fig. 1). The end of the trocar is sharpened laterally and rounded on the back. This is started at right angles through the trachea with the patient's neck somewhat extended, then the handle is raised as the trachea is entered (fig. 3). (If the skin is resistant, a preliminary nick is made with a sharp knife point.) The trocar is then withdrawn. At this point a small vinyl oxygen tube may be inserted. The cannula can then be withdrawn, and the tube sectioned and held in place by a metal collar. Temporary relief could thus be given to many patients in a very short time.

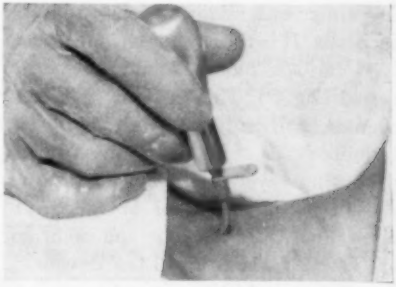


FIGURE 3.

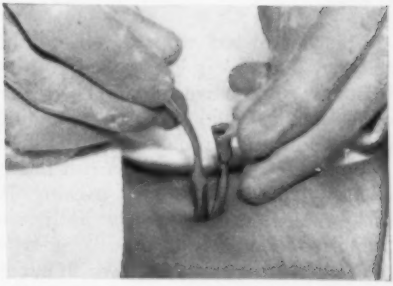


FIGURE 4.

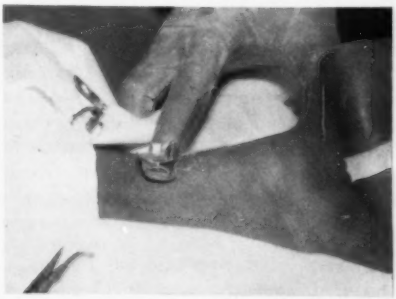


FIGURE 5.

For the usual case, a no. 12 Bard-Parker knife with the curved point ground nearly to the flat (4 of fig. 1) is guided along the slot in the cannula by a bead brazed on the back of the tip, into the trachea (fig. 4). It is inserted halfway along the cannula and is then pushed with the cannula into the trachea, mak-

ing either one midline or two diagonal incisions. It is then removed, and a modified Jackson tube and obturator is inserted (fig. 5). This tube may also have a guide bead on its posterior face and a rounded blade set sagitally in its tip and projecting several millimeters forward. A slot permits removal of the armed obturator. After the tube and obturator are inserted, the original trocar cannula is withdrawn. If the original knife incision is made with a V-tongue, insertion is easier.

This device has worked well on the cadaver, and it has been successful on limited use in the live patient. The method is simple, rapid and easy. Bleeding seems to give no trouble, since the fit is snug. If bleeding should occur, it might be easily controlled by strip packing. If this problem should present itself, we propose to adapt a tapered Luer-type tube with springy side walls which might be expanded, for pressure, by insertion of the inner tube.

FIGURE 6.

After the original tracheotomy tube with cutting trocar is withdrawn, a standard tube has been easily inserted (fig. 6). We hope that this can be routinely done, so that only a limited number of tracheotomes would be required. Instead of the modified Pierce trocar for primary introduction, we now find it simpler to use a stiff cannula with the curve of a tracheotomy tube, and with a cutting-needle blade at the tip of the concavity and a guide slot on the concave curve to within 4 mm. of the tip.

TRANSACTIONS

American Academy of Ophthalmology and Otolaryngology

Official Publication of the American Academy of Ophthalmology and Otolaryngology

Published under the direction of the Editorial Board
WILLIAM L. BENEDICT, Rochester, Minnesota, *Editor*
W. HOWARD MORRISON, Omaha, Nebraska, *Associate Editor*
HENRY L. WILLIAMS, Rochester, Minnesota, *Associate Editor*
Printed by Douglas Printing Company, 109 North 18th Street, Omaha 2, Nebraska

All communications regarding the TRANSACTIONS should be addressed to William L. Benedict, M.D., Executive Secretary-Treasurer, American Academy of Ophthalmology and Otolaryngology, 100 First Avenue Building, Rochester, Minnesota

INDUSTRIAL NOISE AND HEARING LOSS

Notice of a continuing series of articles to appear in forthcoming issues

The otologist is likely to encounter an increasing number of patients whose hearing-loss problems may be related to industrial exposure. The American Academy of Ophthalmology and Otolaryngology has long been aware of this problem and, since 1947, has maintained its own Subcommittee on Noise in Industry. The Subcommittee is a group functioning under the parent Committee on Conservation of Hearing. The work of the Subcommittee has been devoted to research on the relationships of hearing loss and noise exposure and to the dissemination of information to all interested individuals and organizations.

Noise-induced hearing loss is more than a medical problem. In its largest sense, it is a socioeconomic problem with potentially far-reaching implications, of which the physician should be aware. With this thought in mind, the Subcommittee proposes to publish in the TRANSACTIONS a series of questions and answers covering many aspects of the subject of noise-induced hearing loss.

Authorities in the various fields will be asked to answer the questions. They will be persons who have had experience with the specific problems, which will make their opinions of value. It is not, however, the intent of the Subcommittee to give its unqualified endorsement to every statement made in answer to the questions, because areas of contention exist in a subject which embraces so many disciplines and includes so many interests. Nevertheless, we may expect many areas of agreement among the views of the authorities who will be quoted.

One of the reasons for differences of opinion in matters concerning noise-induced hearing loss is the relative paucity of data collected under carefully controlled conditions. This is a deficiency which the Subcommittee on Noise in Industry is attempting to correct, and many of the answers will embody principles based on its findings. A second reason is the multidisciplinary nature of the problem, involving as it does the

skills of the physician, the acoustical engineer, the audiologist, the psychologist, the safety and industrial hygiene engineer, the industrial relations officer, the attorney, the industrial accident commissioner, and the state legislator. The variety of interests inherent in such a group will often lead to differences in the way the problem is posed. Fortunately, there is no difference of opinion among any about the need for solutions. In humans exposed to conditions hazardous to hearing, conservation of hearing is an aspiration to which none can take exception.

The primary motives for this series of articles containing questions and answers are to acquaint the physician with dimensions and terminology in the problem of relating hearing loss to noise exposure and to keep him abreast of the relevant research to date. The scope of the subject matter will necessarily be broad, embracing such categories as hearing tests and problems of rehabilitation, as well as differential diagnosis and prevention of noise-induced hearing loss. The problems of defining and determining permanent noise-induced hearing loss will be discussed in terms of current information. Attention will also be given to the matter of ear protection in noise exposure.

The Subcommittee will be happy to receive any questions submitted by readers, especially those questions generated by material presented in the series. Correspondence should be addressed to the Research Center, Subcommittee on Noise in Industry, 111 North Bonnie Brae Street, Los Angeles 26, California.

As collateral reading matter for most of the articles in the series, the following list of references is proposed.

D. E. Wheeler, Ph.D.
Aram Glorig, M.D.
Research Center
Subcommittee on Noise in Industry

Kryter, K. D.: The effects of noise on man, J. Speech and Hearing Disorders Monograph, 1:1-95, 1950.

Hirsh, I. J.: The Measurement of Hearing, New York: McGraw-Hill Book Company, Inc., 1952.

The Relations of Hearing Loss to Noise Exposure: A Report by Explanatory Subcommittee Z24-X-2, American Standards Association, 1954, American Standards Association, Incorporated, 70 East Forty-fifth St., New York 17, N. Y.

Karplus, H. B., and Bonvallet, G. L.: A noise survey of manufacturing industries. Am. Indust. Hyg. Quart., 14:235-263, 1953.

Wheeler, D. E. and Glorig, A.: The industrial hygienist and ear protection. Am. Indust. Hyg. Quart., 16, 1955.

Davis, H., et al.: Hearing and Deafness, New York, Murray Hill Books, Inc., 1947.

American Academy of Ophthalmology and Otolaryngology: Subcommittee on Noise in Industry, Guide for Conservation of Hearing in Noise, (in press).

Rosenblith, W. A., and Stevens, K. N.: Handbook of Acoustic Noise Control: vol. 2. Noise and Man, Wright Air Development Center Technical Report, 52-204, 1953.

THE PAN-AMERICAN ASSOCIATION OF OPHTHALMOLOGY

It has been gratifying to note that while human relations in many areas of the world have been dangerously strained, ophthalmologists of the Western Hemisphere are being drawn closer together in mutual understanding and scientific endeavor. A large factor in this advance has been the Pan-American Association of Ophthalmology.

The American Academy of Ophthalmology and Otolaryngology sponsored the organization of the Pan-American

Association in 1940 and has watched with satisfaction its growth and increasing influence in the Americas.

At the various Congresses held every four years and at the Interim Meetings, the Latin ophthalmologist and North American ophthalmologist have met, and each has found the other to be very "simpatico." The language barrier has been broken through by simultaneous translation by which each one hears the papers presented in his own language. Individual contacts have stimulated Latin Americans to learn English and North Americans to learn Spanish.

The interchange of scientific information has been greatly increased by the Congresses and the activities of the various committees of the Pan-American Association. Latin Americans who formerly went to Europe are coming to North America for study and observation in ever-increasing numbers. North Americans are being invited to present papers in Latin America. Pathologic slides are being made available to the teaching centers of Latin America. Studies in the prevention of blindness are being carried out. The papers presented at the Academy meeting are being abstracted, translated and distributed to the Latin members of the Pan-American Association of Ophthalmology.

The Thomas D. Allen and Moacyr Alvaro scholarship funds are added to annually by contributions from all over the Western Hemisphere. The granting and supervision of scholarships to the mutual advantage of the individual and institution is an important function of the Association.

Recently the Berens-Zuckerman textbook of ophthalmology, The Eye and Its Diseases, has been translated into Spanish by eighty-six leading Latin American ophthalmologists. This textbook, now published in both English and Spanish, should be a unifying influence in Ophthalmology of the Western World.

Oftalmologia Ibero Americano is the official publication of the Association. Articles are being published in English, Spanish, and Portuguese.

The IV Interim Congress of the Pan-American Association of Ophthalmology will be held in conjunction with the annual meeting of the National Society for the Prevention of Blindness, April 7-10, 1957, in New York.

J. Wesley McKinney, M.D.
Sec'y-Treas. North of Panama

SECOND CRUISE CONGRESS OF THE PAN-AMERICAN ASSOCIATION OF OPHTHALMOLOGY

One of the highlights of the New York Congress will be the announcement of an attractive Caribbean Cruise of 13 days on the Queen of Bermuda, sailing from New York, February 1, 1958. It is possible to make advance registration before the New York Congress, but representatives will be on hand with attractive descriptive literature during the entire Congress at the Hotel Statler.

Make plans to enjoy yourself next February in the mild Caribbean. The cruise will be managed by Mr. Leon V. Arnold, Travel Consultant, Holley Chambers, 33 Washington Square, New York 11, New York.

In Memoriam

John Hedlen Atkinson.....Watertown, New York
November 26, 1951

Robert Beattie.....Detroit, Michigan
August 18, 1956

John Wallace Beil.....Kansas City, Missouri
September 22, 1956

Joseph Bruder.....New York, New York
August 18, 1956

Robert Caldwell.....Little Rock, Arkansas
December 3, 1956

James S. Davis.....South Norwalk, Connecticut
September 30, 1955

Lyn Waller Deichler.....Philadelphia, Pennsylvania
October 2, 1956

James Arthur Downing.....Des Moines, Iowa
December 14, 1956

Guy Rothwell Fisher.....Staunton, Virginia
January 15, 1957

Leonard Fox.....Wyandotte, Michigan
October 7, 1956

Milton Tacitus Gaillard.....Baldwin, New York
October 25, 1956

Thomas J. Goodfellow.....Saratoga Springs, New York
January, 1957

Solomon Mayer Hartzel.....Beverly Hills, California
September 10, 1956

Arthur M. Hauer.....Columbus, Ohio
September 14, 1956

In Memoriam

Ray Whitbeck Hughes.....Lake Worth, Florida
August 28, 1956

LeRoy T. Kincannon.....Birmingham, Alabama
November 28, 1956

Nathan K. Lazar.....Chicago, Illinois
December 14, 1956

Forrest Shetterly LeTellier.....Knoxville, Tennessee
October 15, 1956

Samuel H. Long.....Chattanooga, Tennessee
November 10, 1956

James Ernest McAskill.....Watertown, New York
October 6, 1956

Harley D. Newby.....Rapid City, South Dakota
November 1, 1956

John Henry Ohly.....Brooklyn, New York
December 13, 1956

Francis Peter Quinn.....Dubuque, Iowa
August 8, 1956

George B. Ridout.....La Crosse, Wisconsin
November 26, 1956

Otto Carl Risch.....New York, New York
November 11, 1956

R. Edwards Slocomb.....El Centro, California
December 27, 1954

Abraham B. Spiegelglass.....River Edge, New Jersey
November 13, 1956

TONOMETER CALIBRATION

An Attempt to Remove Discrepancies Found in the 1954 Calibration Scale for Schiotz Tonometers

JONAS S. FRIEDENWALD, M.D.†

I. INTRODUCTION

IN October 1954 the Committee on Standardization of Tonometers of the American Academy of Ophthalmology and Otolaryngology published a revised calibration scale for Schiøtz tonometers based upon the calibration studies of Friedenwald. These studies and the complicated and indirect argument by which calibration estimates were reached have been given in detail in the Decennial Report of the Committee.[1]

With the widespread use of the new calibration scale, certain discrepancies soon became apparent. When tonometric readings are made on the same eye with two different plunger loads, there is a tendency for the pressure estimate (in accordance with the 1954 scale) to be higher with the heavier plunger load. The magnitude of these discrepancies was not large (2 to 3.5 mm. Hg), and if tonometers were being used solely for estimation of the intraocular pressure, these discrepancies could well be neglected as being of no serious clinical import. However, in the use of the tonometer according to the method of Friedenwald[1] for the estimation of ocular rigidity, the current calibration scale gave large errors and inconsistencies. Thus, if the 5.5 gm. and 10 gm. plunger load readings are used with the aid of the 1954 calibration data to estimate the average ocular rigidity on a sufficiently large normal population, one obtains an estimate for the coefficient of ocular rigidity of about .05, whereas the 1954 calibration scale itself was based on the assumption that the average normal coefficient of ocular rigidity was .0215. In this respect, then, the 1954 calibration was found to be self-contradictory.

Moreover, Grant[4] has used the data and the theory of the 1954 calibration to devise the clinical procedure of tonography, with which the rate and facility of aqueous humor outflow may be measured. When tonographic measurements are made on the same eye with two different plunger loads and the coefficient of facility of outflow (C) is estimated with the aid of the 1954 scale (and underlying related scales for P_t* and V_c**), there is a tendency for the estimate of C to be smaller with the heavier plunger load. Goldmann[2] has used this finding to develop a theory of variation in the zero level of the aqueous outflow pressure. Goldmann's theory has certain a priori merits. He is obviously correct in maintaining that the zero level of the aqueous outflow pressure must shift with the rate of aqueous flow, but the degree of this shift may be quite small, as indicated by recent studies of Linnér,[7] and the discrepancies in the tonographic estimates of C with different plunger loads may be due chiefly to errors in the calibration and related data.

†From the Wilmer Ophthalmological Institute of the Johns Hopkins University and Hospital, Baltimore. Dr. Friedenwald died November 5, 1955.

This study was undertaken at the request of, and was supported by, the Committee on Standardization of Tonometers of the American Academy of Ophthalmology and Otolaryngology.

*P_t is the intraocular pressure during tonometry.
**V_c is the volume of the corneal indentation produced by the application of the tonometer.

As against these discrepancies, certain confirmations of the 1954 calibration scale, particularly with respect to the scale for the 5.5 gm. plunger load, should be mentioned. In a series of measurements by Grant, which were included in the original report by Friedenwald,[1] Grant obtained good agreement when he applied the 1954 calibration scale to enucleated eyes, provided the ocular rigidity of each eye was separately measured and the pressure estimate corrected for the deviation of the ocular rigidity from the assumed average normal value. Thus Grant's data show that if the estimate of the average normal ocular rigidity is correct, then the calibration scale for the 5.5 gm. plunger load must be very nearly correct also. Moreover, Grant's estimate of the ocular rigidity in a small series of enucleated eyes turns out to be $.018 \pm .0025$, which is not significantly different from the value .0215 assumed for average normal in the construction of the 1954 scale.

Further confirmation of the 1954 scale for the 5.5 gm. load comes from studies reported by Goldmann using his newly developed applanation tonometer.* Goldmann finds the average normal intraocular pressure to be between 14 and 15 mm. Hg.[3] Measurements at the Wilmer Institute, with an electronic Schiøtz tonometer of well standardized construction, yield an estimated average normal intraocular pressure of 15 to 16 mm. Hg. Moreover, Linnér[5,6] has found that the episcleral venous pressure rises 1 mm. Hg when the subject changes from the erect to the recumbent position. Measurements with the Goldmann applanation tonometer are made in the erect position; with the Schiøtz tonometer they are made with the subject recumbent. Thus these two sets of measurements are in excellent agreement. More precise information in this respect can be obtained only if both types of measurement are made on the same eye. Since the Goldmann tonometer is not as yet available commercially, this further check will have to be deferred.

Since the measurements with the applanation tonometer are independent of ocular rigidity, the good agreement between the Goldmann and Schiøtz estimates of average normal intraocular pressure may be taken to mean that the 1954 calibration scale for the 5.5 gm. plunger load is substantially correct, particularly in the region of scale readings 4 to 6, where most normal readings are found. If we take this together with Grant's confirmatory measurements already referred to, we must conclude that the estimate of average normal ocular rigidity used in establishing the 1954 calibration is also substantially correct.

It follows from all this that any efforts to remove the discrepancies in the 1954 calibration scale should be done without introducing significant changes in the calibration scale for the 5.5 gm. load, without significant alteration of the estimates of P_t and V_C for the 5.5 gm. load, and without significant change in the estimate of the average normal value of the coefficient of ocular rigidity.

II. ESTIMATE OF THE DISCREPANCIES

As has been noted above, preliminary clinical observations with the 1954 calibration scale showed that when the same eye was measured with two different plunger loads, the pressure estimate with the heavier load tended to be higher. In order to reveal the precise magnitude of the discrepancy, large numbers of such measurements needed to be systematically collected. Under the initiative of Dr. Peter Kronfeld, several series of paired measurements were made by Kronfeld, by Ballintine, and by

*Demonstrated at the International Congress of Ophthalmology, New York, 1954.

Grant and Trotter. Several different tonometers were used, and the series varied in the proportion of subjects with glaucoma or in whom glaucoma was suspected. The most extensive studies involved comparison of the 5.5 gm. with the 10 gm. load. The results are given in table I, in which the mean tonometer scale reading for each plunger load in each series is listed. For the comparison between the 5.5 gm. load and the 10 gm. load, the unweighted mean of the means of each series is computed. For this pair of means, the intraocular pressure is computed according to the 1954 scale. The discrepancy is recorded in terms of the excess pressure estimate with the heavier load. Similar estimates of the discrepancies for the 5.5 gm. versus 7.5 gm. loads and the 7.5 gm. versus 15 gm. loads are given. The standard errors of the discrepancies have been computed and are negligibly small.

The calculation of the discrepancy in millimeters of mercury for the means of the paired readings reduces each set of data to a single number. In the data pertaining to the 5.5 gm. versus 10 gm. load, it is possible to construct the regression line for the 10 gm. versus the 5.5 gm. reading. It is found that this line is nearly parallel to the line similarly drawn between expected pairs of readings on the basis of the 1954 calibration (fig. 1). The discrepancy in scale units is nearly the same for each of these sets of data taken separately as it is for the total data pooled together.

For the 5.5 gm. versus the 7.5 gm. loads and the 7.5 gm. versus 15 gm. loads, we have in each case only a single set of readings. However, the regression lines for the paired readings can again be constructed and again are found to be substantially parallel to the lines drawn through expected paired values

TABLE I

PAIRED READINGS WITH TWO PLUNGER LOADS

INVESTIGATOR	NUMBER OF CASES	MEAN SCALE READING	P_o MM. HG	MEAN SCALE READING	P_o MM. HG	DISCREPANCY (ΔP_o) MM. HG
		5.5 gm. load versus 10 gm. load				
Ballintine	109	5.54		9.93		
	219	5.53		9.90		
	257	5.22		9.59		
Grant & Trotter	230	5.00		9.04		
Kronfeld	183	4.72		9.55		
	78	3.95		8.55		
	78	5.30		9.72		
Summary 5.5 gm. versus 10 gm. load	1154	5.04	17.24	9.47	21.59	4.35 ± .00
		5.5 gm. load versus 7.5 gm. load				
Kronfeld	208	4.11	20.17	6.47	21.99	1.82 ± .05
		7.5 gm. load versus 15 gm. load				
Kronfeld	174	6.36	22.27	12.31	24.67	2.40 ± .01

according to the 1954 calibration. The discrepancies measured at the mean values are, therefore, substantially characteristic of the whole group of data. It was necessary to establish this fact; otherwise, abolition of the discrepancy at

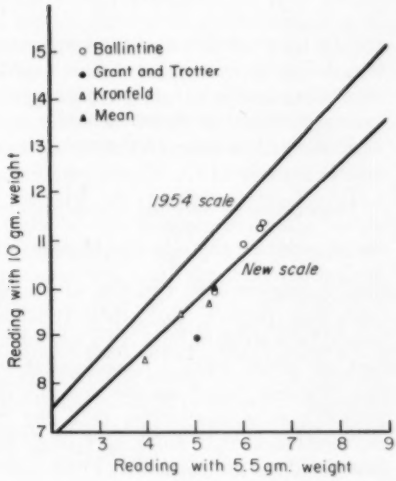


FIGURE 1.

the mean values of the reading might merely make other discrepancies break out at other scale readings. Though the data are not included in these series, Dr. Kronfeld reports that they indicate that the discrepancy in scale units is less at low scale readings than at middle scale readings.

There are several ways in which the discrepancies could be abolished. The simplest procedure would be to reduce the calibration scales for all but the 5.5 gm. load by amounts corresponding to the discrepancies. This procedure would yield calibration scales suitable for tonometry, but the theoretical bases for estimating ocular rigidity and for the tonographic calculations would be thrown overboard. Since the 1954 calibrations are, in fact, not grossly unsatisfactory for routine tonometry, the gains by this adjustment would be small, the losses great.

In the previous calibration study, direct experimental estimates were obtained for the intraocular pressure during tonometry (P_t) and the volume of the corneal deformation produced by the tonometer (V_C). The intraocular pressure before tonometry (P_O) was then calculated by the formula

$$(1) \quad \text{Log } P_O = \text{Log } P_t - K V_C$$

where K is the coefficient of ocular rigidity. On the basis of paired readings with the 5.5 gm. load and the 10 gm. load made on normal eyes many years earlier, the average normal value for K was estimated as .0215, and this was the value used in computing the 1954 scale. The tonometer used for these paired readings was an ancient one of Oslo manufacture, which has long since been discarded and lost. Crude measurements on this instrument showed that it deviated markedly from current standards, but these measurements were grossly incomplete by modern requirements. A simple solution would be to abandon these old inaccurate readings and to take the data in table I for a new estimate of K. The average value of K computed from these data on the assumption that previous estimates of P_t and V_C are correct turns out to be about .05. If this were correct, the average normal intraocular pressure would be equal to or less than the average episcleral venous pressure. Outflow pressure and rate of flow would be zero. Tonography would be meaningless. Discrepancies between Schiøtz and Goldmann findings would be greater than any of the discrepancies we are seeking to correct. This procedure would be contrary to the desiderata outlined in section I above, in which it was concluded that the 1954 scale for

the 5.5 gm. weight and the 1954 estimate for the average normal ocular rigidity should not be significantly altered. It follows that the discrepancies in the 1954 calibration scale cannot be disposed of without a re-examination and revision of the experimentally determined estimates of P_t and V_C.

III. ESTIMATION OF P_t

P_t has been defined as the intraocular pressure during tonometry. It is determined experimentally by "open manometer" measurements of the type described by Schiøtz in his initial calibration studies. When the tonometer rests on the eye, the plunger indents the cornea, causing it to sink until the upward force of the intraocular pressure operating over the area of the indentation is equal to the downward force of the weight of the plunger assembly. This is expressed by the equation

$$(2) \quad W = P\,A,$$

in which W is the weight of the plunger assembly, P the intraocular pressure, A the area of the plunger indentation. It would seem likely that for a given depth of plunger indentation, i.e., for a given tonometer scale reading, the shape of the indentation and hence the area of the indentation would be the same irrespective of whether the indentation was produced by a small plunger load at a low intraocular pressure or by a larger plunger load at a higher intraocular pressure. It follows from this hypothesis that a plot of $\frac{W}{P}$ versus tonometer scale reading (R) should yield a single-valued function irrespective of the plunger assembly weight (W) used. This hypothesis was tested in the previous calibration study and found to be correct within the limits of reliability of the measurements.

These considerations led to a curve-fitting exercise in which the experimental data were plotted $\frac{W}{P}$ versus R. The simplest curve, and one which appeared to fit the data reasonably well, is a straight line. The experimental data were, therefore, fitted to the equation

$$(3) \quad \frac{W}{P} = a + b\,R,$$

and the curve fitting consisted in selecting the best values for the empirical constants a and b. Before considering the estimated values of these constants, it is desirable to give some further consideration to equation (3).

The argument outlined above justifies the expectation that $\frac{W}{P}$ should approximate a single-valued function of R, but does not require that that function should be a straight line. As a matter of fact, an earlier (1937) consideration of this problem, based on the analysis of Schiøtz's open manometer data, led to the conclusion that those data could be best fitted to an equation of the form

$$(4) \quad \frac{W}{P} = a + b\,R + c\,R^2$$

In the experimental study leading to the 1954 calibration, open manometer measurements were made on rabbit, cat, pig, and human eyes. No consistent differences were found among the species studied; the estimated value of c, applying equation (4) to the data, was found to be small, sometimes positive and sometimes negative. No basis was, therefore, found for preferring the more complicated equation (4) to the simpler equation (3).

It should be pointed out that Schiøtz, in fitting curves to his own open manometer data, adopted an equation of the form

$$(5) \quad \frac{W + d}{P} = a + b\,R$$

The difference between this and equation

(3) would appear to depend on the definition of W. Schiøtz defined W as the weight of the plunger, neglecting the additional force applied to the plunger by the hammer and lever arm resting on it. Since this force varies from instrument to instrument with unspecified variations in the construction of hammer and pointer, it has been the fixed policy of the Committee on Standardization of Tonometers to consider the total weight of the plunger assembly as the actual plunger load. Thus in equation (3), W represents the weight of the plunger assembly, while in equation (5), W represents the weight of the plunger, W + d that of the plunger assembly. The weight of the plunger assembly varies slightly with the position of the pointer. However, the total variation from scale reading 5 to scale reading 18 was only 0.22 gm. in the reference standard instrument used for the calibration studies and could be safely neglected. Schiøtz also found no need to consider this variation in dealing with his own open manometer data.

Returning to a consideration of equation (3), it was found in the previous calibration study[1] [table II, page 104 of the reference] that the open manometer data on different sets of eyes yielded estimates for the empirical constant a which varied over a rather narrow range, while the estimates for the constant b varied much more widely. The choice of a particular value of b was, therefore, of necessity somewhat arbitrary. The value chosen, .0091, was that determined on cats' eyes by the technician whose measurements seemed to me the most reliable of those assembled in the study. It might equally well have been decided to use the value .0101, which represented the mean of all the sets of experimental data, or the value .0115, which represented the mean of the estimates based on my own and on Schiøtz's open manometer measurements on human eyes. Thus the estimate of b used in the 1954 calibration might be increased by 10 per cent, or even 15 per cent, without doing violence to the experimental data on which that estimate was based.

Perhaps a better estimate of b could be obtained by a very large increase in the number of open manometer measurements, but the total number of measurements summarized in table II of the calibration study already amounted to over 2000 individual data, and a large increase in this number of observations would be very onerous indeed.

It is evident that an increase in the estimated value of b would tend to diminish the discrepancies in the 1954 calibration. Moreover, the estimation of the discrepancies itself involved over 2500 tonometric readings, as summarized in table I. The question, therefore, presents itself as to how we can use these discrepancy measurements to obtain a "better" value of b for equation (3), better, that is, than the value used in the 1954 calibration. The choice here is necessarily arbitrary, but it has seemed worth while to find out how much the estimate of b needs to be raised in order to reverse one of the three discrepancies listed in table I above. If this change in the estimate of b does not do violence to the experimental data of the calibration study and if it does not make unacceptably large changes in the estimate of P_t for the 5.5 gm. weight (which we have already decided should be disturbed as little as possible), then this may be accepted as a new and "better" estimate of b.

In the actual computation, equation (3) was first converted to yield pressure estimates in millimeters of mercury instead of grams per square centimeter. [See equation (6), page 110 of the calibration study.[1]] On the scale based on millimeters of mercury, the previously chosen value of b was .01227.

TABLE II

ESTIMATED DISCREPANCIES (Δ P) FOR THE MEAN PAIRED TONOMETER READINGS FOR ARBITRARY VALUES OF THE EMPIRICAL CONSTANT b

Δ P MM. HG

ASSUMED VALUE OF b	PLUNGER LOADS		
	5.5 VS. 10 GM.	5.5 VS. 7.5 GM.	7.5 VS. 15 GM.
.01227*	+3.43	+1.82	+2.40
.013	+2.82	+1.36	+1.13
.0135	———	———	+0.36
.0138	+1.85	+0.91	—0.15

*Assumed value of b in 1954 calibration.

Estimates of the discrepancy between various plunger loads for various arbitrarily chosen values of b are shown in table II. It is found that an increase of 12 per cent in the estimated value of b just suffices to reverse the discrepancy between the mean readings with 7.5 gm. and 15 gm. loads, but reduces the discrepancies between the 5.5 gm. and 10 gm. loads, and between the 5.5 gm. and 7.5 gm. loads, by only about 30 per cent. An increase of 12 per cent in the estimated value of b does not do violence to the experimental data of the calibration study. In table III, the calculated values of P_t are given on the basis of this new estimate of b. Comparing this table with the corresponding table IV, page 110 of the calibration study,[1] it is found that the maximum change in the estimate of P_t for the 5.5 gm. weight is a decrease of 1.51 mm. Hg, which would not appear to be an unacceptably large change in estimate.

The argument just given makes it clear that an increase of 12 per cent in the estimate of b is not unacceptably large. Is it possibly still too small? This is a question that cannot be answered at this point, but it will be reconsidered later.

IV. ESTIMATION OF V_C

In the calibration experiments, the volume of the corneal indentation produced by the tonometer was recorded at different intraocular pressures and at different tonometer plunger loads. Tonometer scale readings were also observed in order to be sure that the previously determined relation of tonometer scale reading to intraocular pressure (P_t) was being maintained, but these data were not further used. Plotting intraocular pressure (P_t) versus the volume of the indentation (V_C) yielded a curve resembling a rectangular hyperbola. Plotting Log P_t versus Log V_C yielded results conforming reasonably to a straight line for each plunger load. The formula for such a straight line is

$$(6) \quad \text{Log } P_t = B - \frac{1}{N} \text{ Log } V_C$$

or

$$(7) \quad P_t{}^N V = \text{Constant},$$

a not unusual relation between pressure and volume in many physical and physiological situations. The curve-fitting problem, therefore, resolved itself into finding the best value for B and N for each plunger load. The data were rather widely scattered, and the initially estimated values of B and N, when plotted

TABLE III

INTRAOCULAR PRESSURE (P_i) DURING TONOMETRY (MM. HG)

SCALE READING	PLUNGER LOAD			
	5.5 GM.	7.5 GM.	10.0 GM.	15.0 GM.
0.0	51.40	70.09	93.46	140.19
0.5	48.29	65.85	87.80	131.69
1.0	45.53	62.09	82.78	124.17
1.5	43.07	58.73	78.31	117.46
2.0	40.86	55.72	74.29	111.44
2.5	38.87	53.00	70.67	106.01
3.0	37.06	50.54	67.39	101.08
3.5	35.42	48.29	64.39	96.59
4.0	33.91	46.24	61.65	92.48
4.5	32.53	44.35	59.14	88.70
5.0	31.25	42.61	56.82	85.23
5.5	30.07	41.01	54.67	82.01
6.0	28.98	39.52	52.69	79.03
6.5	27.96	38.13	50.84	76.26
7.0	27.01	36.84	49.12	73.67
7.5	26.13	35.63	47.51	71.26
8.0	25.30	34.50	46.00	69.00
8.5	24.52	33.44	44.58	66.87
9.0	23.79	32.44	43.25	64.88
9.5	23.10	31.50	42.00	63.00
10.0	22.45	30.61	40.82	61.22
10.5	21.83	29.77	39.70	59.55
11.0	21.25	28.98	38.64	57.96
11.5	20.70	28.23	37.64	56.45
12.0	20.18	27.51	36.68	55.03
12.5	19.68	26.83	35.78	53.67
13.0	19.20	26.19	34.92	52.37
13.5	18.75	25.57	34.09	51.14
14.0	18.32	24.98	33.31	49.97
14.5	17.91	24.42	32.56	48.84
15.0	17.52	23.89	31.85	47.77
15.5	17.14	23.37	31.16	46.74
16.0	16.78	22.88	30.51	45.76
16.5	16.43	22.41	29.88	44.82
17.0	16.10	21.96	29.27	43.91
17.5	15.78	21.52	28.69	43.04
18.0	15.48	21.10	28.14	42.21
18.5	15.18	20.70	27.60	41.40
19.0	14.90	20.31	27.09	40.63
19.5	14.62	19.94	26.59	39.88
20.0	14.36	19.58	26.11	39.16

versus plunger load, were somewhat ragged. Free-hand smoothing of these plots was undertaken, yielding the sets of values of B and N shown in table IX of the calibration study.[1] The smoothing involved shifts in estimated values of B and N of up to ± .02. It would appear that the chosen values of B and N were afflicted with uncertainties of approximately this magnitude. Preliminary trials showed that changes in the assumed values of B were from two to four times as effective in reducing residual discrepancies as equal changes in N. It was decided, therefore, to leave the previously estimated values of N undisturbed and to find out what changes in the estimated values of B were required to bring about the desired changes in the calibration scale. The first step is to find a new "corrected" value for B for the 5.5 gm. load.

It should be remembered that in view of arguments already given above, it appeared desirable to alter the calibration scale for the 5.5 gm. weight as little as possible—in particular, to alter it not at all in the neighborhood of the average normal readings. It was thus decided that for scale reading 5, the P_O value should be 17.30, as in the 1954 calibration. The revised estimate of P_t is already known, as indicated in table III. Moreover, it had also been decided not to shift the estimate of average normal ocular rigidity from its previously determined value of .0215. Consequently, one could write equation (1)

$$(1)\quad \text{Log } P_O = \text{Log } P_t - K\,V_C \quad \text{or}$$
$$1.23805 = 1.49485 - (.0215)\,V_C$$

With K, P_O and P_t all known for scale reading 5.0, V_C could be calculated for this scale reading (11.94 cu. mm.). Moreover, inserting this value of V_C into equation (6)

$$(6)\quad \text{Log } P_t = B - \frac{1}{2.016}\text{Log } V_C \quad \text{or}$$
$$1.49485 = B - \frac{1.07700}{2.016},$$

one obtains an estimate of B for the 5.5 gm. weight as 2.029. With this value of the empirical constant determined, estimates of V_C and of P_O for any scale reading for the 5.5 gm. plunger load can be calculated. The results are shown in tables IV and V. Comparing the new V_C and P_O estimates for the 5.5 gm. load with those of the 1954 calibration, it is easy to see that the changes introduced for this plunger load are small. The change in the estimate of V_C amounts to less than 1 cu. mm. The change in the estimate of P_O between scale readings 3 and 13 is less than 0.2 mm. Hg. The new calibration scale for the 5.5 gm. weight is just as well confirmed by Grant's and Goldmann's measurements as was the almost identical 1954 scale.

In table I, it is seen that the average readings in the set of paired tonometries with the 5.5 gm. and 7.5 gm. weights were 4.11 and 6.47 respectively. In order that the discrepancy in the calibration scale should be abolished, it is required that scale reading 4.11 with the 5.5 gm. weight and 6.47 with the 7.5 gm. weight should indicate the same intraocular pressure. Since the revised calibration scale for the 5.5 gm. weight has already been established, the P_O value corresponding to scale reading 4.11 can readily be calculated. The estimate is 20.16 mm. Hg. We now assume that this is also the pressure corresponding to scale reading 6.47 with the 7.5 gm. load. With this information we can proceed to calculate the empirical constant B for the 7.5 gm. load, using the same steps which in the preceding paragraphs led to the estimate of B for the 5.5 gm. load. Precisely similar arguments, beginning with the data on paired readings in table I, lead to estimates of values for B for the 10 gm. and 15 gm. loads. With all the empirical constants determined, tables for the estimated volumes of corneal indentation (V_C, table IV) and the tonometric calibration tables (P_O, table V) can be computed. The curve-fitting equations used in computing tables III, IV and V are summarized in table VI.

For convenience, I have also computed a revised table for tonographic calculations (table VII), based on the revised calibration scale. A revised pressure-rigidity nomogram is presented in figure 2, and corresponding tables for paired readings with the 5.5 gm. and 10 gm. loads and the 7.5 gm. and 15 gm. loads, respectively, are given in tables VIII and IX.

V. COMMENTS

The arguments presented above may be very briefly recapitulated. The clinical use of the 1954 Schiøtz Tonometer Calibration Scale has revealed certain discrepancies in that scale. When paired

TABLE IV

VOLUME OF CORNEAL INDENTATION (V_c) IN CUBIC MILLIMETERS

SCALE READING	PLUNGER LOAD			
	5.5 GM.	7.5 GM.	10.0 GM.	15.0 GM.
0.0	4.38	3.43	2.73	1.92
0.5	4.96	3.93	3.15	2.24
1.0	5.59	4.47	3.60	2.58
1.5	6.25	5.04	4.09	2.96
2.0	6.95	5.65	4.62	3.37
2.5	7.69	6.30	5.19	3.81
3.0	8.46	6.99	5.78	4.28
3.5	9.27	7.71	6.42	4.79
4.0	10.12	8.48	7.10	5.33
4.5	11.01	9.28	7.81	5.90
5.0	11.94	10.13	8.56	6.51
5.5	12.90	11.01	9.36	7.16
6.0	13.89	11.93	10.19	7.84
6.5	14.94	12.89	11.06	8.55
7.0	16.01	13.89	11.97	9.31
7.5	17.12	14.94	12.92	10.10
8.0	18.27	16.02	13.92	10.93
8.5	19.46	17.15	14.96	11.81
9.0	20.69	18.32	16.04	12.72
9.5	21.95	19.54	17.16	13.67
10.0	23.25	20.79	18.32	14.67
10.5	24.60	22.08	19.53	15.70
11.0	25.97	23.41	20.79	16.78
11.5	27.38	24.78	22.08	17.90
12.0	28.82	26.22	23.43	19.06
12.5	30.32	27.68	24.81	20.26
13.0	31.87	29.17	26.24	21.52
13.5	33.43	30.73	27.73	22.81
14.0	35.03	32.33	29.25	24.15
14.5	36.66	33.97	30.82	25.54
15.0	38.33	35.64	32.42	26.97
15.5	40.06	37.37	34.10	28.45
16.0	41.81	39.13	35.79	29.97
16.5	43.62	40.94	37.55	31.54
17.0	45.45	42.79	39.38	33.17
17.5	47.32	44.71	41.23	34.84
18.0	49.19	46.67	43.11	36.54
18.5	51.17	48.69	45.07	38.32
19.0	53.13	50.71	47.05	40.13
19.5	55.20	52.77	49.11	42.01
20.0	57.23	54.91	51.21	43.93

readings are made on the same eye with two different plunger loads, there is a tendency for a higher pressure estimate with the heavier plunger load. As the result of extensive tests initiated by Dr. Kronfeld, the extent of the discrepancies has been estimated (table I). Arguments are presented leading to the conclusion that the 1954 calibration scale for the 5.5 gm. load was essentially correct and should be disturbed as little as possible. These arguments also led to the conclusion that the 1954 estimate of the average normal value for the ocular rigidity coefficient required no change. We were thus led to inquire what changes in the empirical constants, used in the curve fitting on which the 1954 calibration was based, would abolish the discrepancies found in that calibration. It was found that the required adjustment could be reached by distributing the changes over five of the eleven empirical constants used in the

TABLE V

CALIBRATION SCALE FOR SCHIØTZ TONOMETERS
P MM. HG, REVISED 1955

SCALE READING	PLUNGER LOAD			
	5.5 GM.	7.5 GM.	10.0 GM.	15.0 GM.
0.0	41.38	59.14	81.65	127.45
0.5	37.78	54.21	75.11	117.87
1.0	34.52	49.76	69.27	109.28
1.5	31.61	45.76	63.96	101.44
2.0	28.97	42.12	59.10	94.32
2.5	26.56	38.80	54.66	87.99
3.0	24.38	35.76	50.62	81.78
3.5	22.38	32.97	46.86	76.20
4.0	20.55	30.39	43.38	71.03
4.5	18.86	28.01	40.18	66.23
5.0	17.30	25.81	37.19	61.75
5.5	15.88	23.78	34.40	57.55
6.0	14.57	21.89	31.82	53.61
6.5	13.35	20.14	29.40	49.94
7.0	12.23	18.52	27.16	46.46
7.5	11.20	17.01	25.06	43.22
8.0	10.24	15.61	23.09	40.17
8.5	9.36	14.31	21.26	38.13
9.0	8.54	13.10	19.55	34.56
9.5	7.79	11.97	17.96	32.02
10.0	7.10	10.94	16.48	29.61
10.5	6.46	9.98	15.10	27.37
11.0	5.87	9.09	13.81	25.26
11.5	5.34	8.28	12.62	23.27
12.0	4.85	7.51	11.50	21.42
12.5	4.39	6.82	10.48	19.69
13.0	3.96	6.18	9.53	18.05
13.5		5.59	8.64	16.53
14.0		5.04	7.83	15.12
14.5		4.54	7.08	13.70
15.0		4.09	6.40	12.57
15.5			5.76	11.43
16.0			5.19	10.38
16.5			4.66	9.41
17.0			4.17	8.50
17.5				7.67
18.0				6.92
18.5				6.21
19.0				5.57
19.5				4.87
20.0				4.45

TABLE VI

SUMMARY OF CURVE-FITTING EQUATIONS

EQUATION	PLUNGER LOAD
$P_t = \frac{W}{0.107 + 0.0138\ R}$	all
$\text{Log } V_c = 2.016\ (2.029 - \text{Log } P_t)$	5.5 gm.
$\text{Log } V_c = 2.174\ (2.092 - \text{Log } P_t)$	7.5 gm.
$\text{Log } V_c = 2.300\ (2.160 - \text{Log } P_t)$	10.0 gm.
$\text{Log } V_c = 2.455\ (2.262 - \text{Log } P_t)$	15.0 gm.
$\text{Log } P_o = \text{Log } P_t - 0.0215\ V_c$	all

TABLE VII

CHANGE IN OCULAR VOLUME (Δ V IN CU. MM.) FOR VARIOUS PLUNGER WEIGHTS WHEN THE TONOMETER READING FALLS FROM O TO R

$$\Delta V = \frac{1}{K} \log \frac{P_{to}}{P_{tR}} + V_{cR} - V_{co}^{*}$$

SCALE READING R	PLUNGER LOAD			
	5.5 GM.	7.5 GM.	10.0 GM.	15.0 GM.
0.0	0	0	0	0
0.5	1.84	1.93	1.69	1.58
1.0	3.66	3.49	3.32	3.11
1.5	5.44	5.18	4.93	4.61
2.0	7.21	6.85	6.53	6.09
2.5	8.95	8.52	8.11	7.54
3.0	10.69	10.17	9.66	8.97
3.5	12.41	11.81	11.22	10.40
4.0	14.14	13.46	12.77	11.81
4.5	15.87	15.09	14.32	13.23
5.0	17.61	16.75	15.88	14.64
5.5	19.35	18.41	17.46	16.07
6.0	21.09	20.07	19.04	17.40
6.5	22.86	21.76	20.63	18.93
7.0	24.63	23.45	22.23	20.39
7.5	26.41	25.18	23.86	21.85
8.0	28.21	26.91	25.51	23.33
8.5	30.03	28.67	27.18	24.84
9.0	31.87	30.45	28.87	26.36
9.5	33.73	32.27	30.59	27.91
10.0	35.60	34.09	32.34	29.49
10.5	37.52	35.95	34.09	31.07
11.0	39.43	37.82	35.90	32.70
11.5	41.37	39.72	37.72	34.35
12.0	43.33	41.68	39.59	36.03
12.5	45.33	43.65	41.47	37.73
13.0	47.38	45.62	43.40	39.49
13.5		47.67	45.37	41.26
14.0		49.74	47.36	43.07
14.5		51.84	49.39	44.92
15.0		53.94	51.43	46.80
15.5			53.56	48.72
16.0			55.67	50.67
16.5			57.85	52.65
17.0			60.10	54.70
17.5				56.77
18.0				58.87
18.5				61.04
19.0				63.23
19.5				65.48
20.0				67.77

*Subscripts O and R refer to tonometer scale readings zero and R.

1954 calibration. Reasons for limiting the changes to these five constants are given above.

Under the procedure adopted, once the change in the empirical constant b of the equation (3) has been decided, the necessary changes in the four different values of B, equation (6), one value for each plunger load, will have been determined. The distribution of the changes between b and the four B's is, therefore, arbitrary. If b had been left at the value .01227 assumed in the 1954 calibration, then B for the 5.5 weight also would have been unchanged, but the values of B's for the heavier

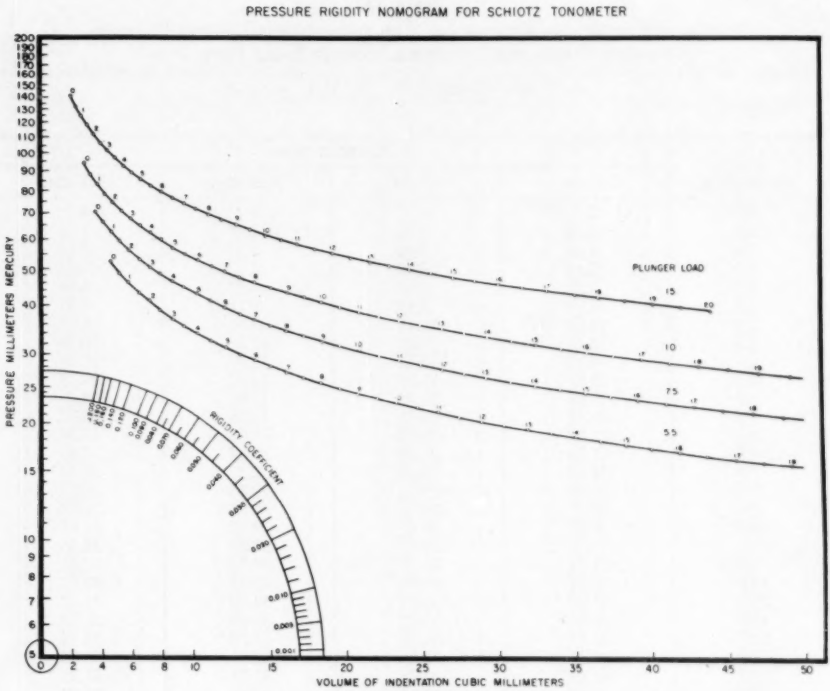


FIGURE 2.

loads would all have required substantial increase in order to abolish the discrepancies in the 1954 scale.

As the chosen value for b is increased, the value of B for the 5.5 gm. weight requires reduction if the pressure estimate at scale reading 5 is to be kept the same as it is in the 1954 scale. The B's for the heavier weights are also correspondingly reduced from the maximum value corresponding to b unchanged. Minimum net changes in the B's correspond to b values of about .0133, and this might perhaps have been used as a basis for allocating the required changes. However, a maximally rigid economy in the corrections did not seem indicated and, in any case, the chosen value of b, .0138, turns out to be not far from that associated with minimal net changes in the B's. A further increase in the chosen value of b would increase the net changes required in the B's. This is one reason for concluding that the change chosen in respect to b was not too small. Within the limits of available information, the distribution of correction factors does not appear unreasonable.

In the introduction to this report, it was pointed out that discrepancies in the 1954 calibration manifested themselves in three ways:

1. When tonometry was performed with two different plunger loads on the same eye, there was a tendency for the pressure estimate to be higher with the higher weight. The correction procedure

TABLE VIII

PRESSURE AND RIGIDITY TABLE FOR PAIRED READINGS WITH 5.5 AND 10.0 GM. WEIGHTS

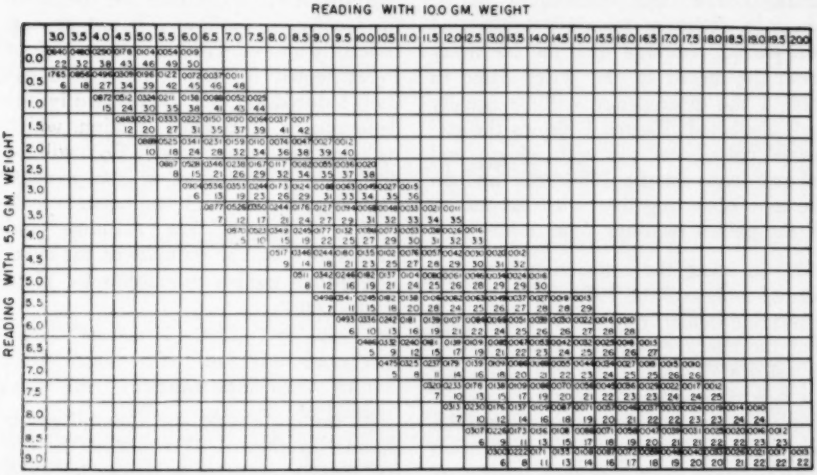
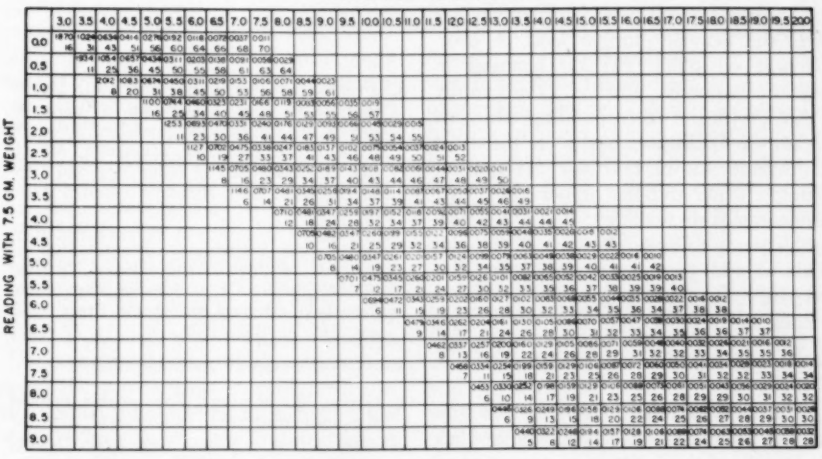


TABLE IX

PRESSURE AND RIGIDITY TABLE FOR PAIRED READINGS WITH 7.5 AND 15.0 GM. WEIGHTS



which we have followed has been designed to abolish the discrepancy for the average of a large number of paired readings. It is not certain a priori that for paired readings that lie far away from the means of the series listed in table I the discrepancy will be equally well abolished. Figure 1 shows the expected paired readings with 5.5 gm. and 10 gm. loads on the 1954 scale and on the new scale, together with the means of the paired readings from table I.

2. In using the calibration data and related tables of the 1954 calibration to determine ocular rigidity, it was found that the average normal ocular rigidity so estimated differed grossly from the average normal ocular rigidity assumed in computing the 1954 scale. This self-contradictory aspect of the calibration scale has now been abolished insofar as the paired mean measurements shown in table I are representative of the average normal community.

3. When the empirical constants assumed in the 1954 calibration are used for the purposes of tonographic calculations, it is found that the estimate of the facility of outflow of the same eye reached by tonography with two different plunger loads tends to be smaller with the heavier plunger load. A comparison of table VII on changes in ocular volume during tonography ($\triangle V$) with the corresponding tables of Grant or Ballintine based on the 1954 calibration shows that for the heavier plunger loads and the higher ranges of tonometer scale readings, $\triangle V$ in the new tables tends to be larger than in the old. This should tend to diminish the discrepancy in the tonographic measurements, but it is not possible to estimate to what extent the discrepancy has been abolished.

The $\triangle V$ calculation for the 5.5 gm. weight is not appreciably changed as the result of the calibration corrections; thus, for measurements with this plunger load the numerator of the fraction used by Grant to calculate the coefficient of facility of outflow will not be significantly altered. However, the value of P_t estimated for the 5.5 gm. load has been reduced slightly. Consequently, the denominator of Grant's fraction, which includes the factor $(P_t - P_o)$ will be diminished. This effect will be percentually greater at high tonometer scale readings than at low readings and should increase the estimate of the average normal facility of outflow by 15 to 20 per cent.

SUMMARY

At the request of the Committee on Standardization of Tonometers, the effort has been made to refine the 1954 calibration scale so as to eliminate certain discrepancies which had become evident in the clinical use of this scale. The results of this effort are embodied in the tables of the present report. Reasons are given for hoping that these new tables represent a closer approach to the truth. There can never be a final and absolutely correct tonometer calibration.

REFERENCES

1. Friedenwald, Jonas S., Chairman: Decennial Report of the Committee on Standardization of Tonometers: Standardization of Tonometers, Rochester, Minnesota, American Academy of Ophthalmology and Otolaryngology, 1954, chaps. VII and VIII.

2. Goldmann, H.: Some remarks about fluorometric and tonographic determination of the rate of flow of the aqueous, cited in XVII Concilium Ophthalmologicum, Acta, Canada, University of Toronto Press, 1955, vol. III, pp. 1573-1579.

3. ———: Personal communication.

4. Grant, W. Morton: Tonographic method for measuring the facility and rate of aqueous flow in human eyes, Arch. Ophth., 44:204-214 (Aug.) 1950.

5. Linnér, Erik: Measurement of the pressure in Schlemm's canal and in the anterior chamber of the human eye, Experientia, 5:451-452 (Nov.) 1949.

6. ———: The outflow pressure in normal and glaucomatous eyes, Acta ophth., 33: 101-116, 1955.

7. ———: Further studies of the episcleral venous pressure in glaucoma, Am. J. Ophth., 41:646-651 (April) 1956.

TONOMETER CALIBRATION
Empirical Validation

THE COMMITTEE ON STANDARDIZATION OF TONOMETERS

PETER C. KRONFELD, M.D., *Chairman*

ON October 1, 1955, Dr. Jonas S. Friedenwald submitted the foregoing paper on tonometer calibration to the Committee with the request for further empirical validation of the new scale (hereafter referred to as the 1955 scale). He specifically asked for paired tonometric measurements with the 5.5 gm. and the 10 gm. weights on eyes with high ocular tension.

The value of tonometric readings with different plunger weights has become more and more apparent as the difficulties and uncertainties inherent in any attempt to determine the absolute pressure equivalents of the tonometric reading have been recognized. These difficulties and uncertainties are brought out in Friedenwald's section on tonometer calibration in the Decennial Report of this Committee, as well as in the foregoing, Friedenwald's last, paper on tonometer calibration. Under these circumstances, the self-consistency of any calibration scale becomes a most valuable criterion of its reality and reliability. The obvious test for self-consistency is to subject the same eye to tonometry with two different plunger weights. These two measurements are expected to yield the same result in millimeters of intraocular pressure or to differ by not more than one or two millimeters in single tests on eyes with average ocular rigidity. A series of such measurements should show no significant difference between the means of the pressure estimates derived from tonometric measurements with two different weights.

It was most disturbing to the Committee when a statistically significant difference between such means was found to be inherent in the 1954 scale. It meant an inconsistency within the scale which, unfortunately, had not been detected prior to its release in the fall of 1954. At the Committee's request, Dr. Friedenwald undertook to re-examine his data with the aim of bringing his 1954 scale more closely in line with the results of paired tonometric readings on human eyes made available to him by members of the Committee. By a process of mathematical re-evaluation of his calibration data and without doing injustice to any part of them, Dr. Friedenwald arrived at new calibration curves, the 1955 scale, which is the principal content of the preceding paper.

Since paired tonometric readings on human eyes had first disclosed the inconsistency within the 1954 scale, it seemed appropriate to test the new 1955 scale by applying it to the most representative series of paired readings that could be obtained. The Committee, therefore, set out to select data from which

TABLE I

PAIRED TONOMETRIC MEASUREMENTS WITH 5.5 GM. AND 10 GM. PLUNGER WEIGHTS

SERIES*	NUMBER OF EYES	MEAN OF SCALE READINGS WITH 5.5 GM. WEIGHT	MEAN OF SCALE READINGS WITH 10 GM. WEIGHT
B_1	77	3.82	8.32
B_2	204	5.38	9.98
B_3	99	6.77	11.49
B_4	26	8.40	13.20
K_1	36	1.53	6.54
K_2	60	3.01	7.91
K_3	59	4.52	9.10
K_4	40	6.00	10.30

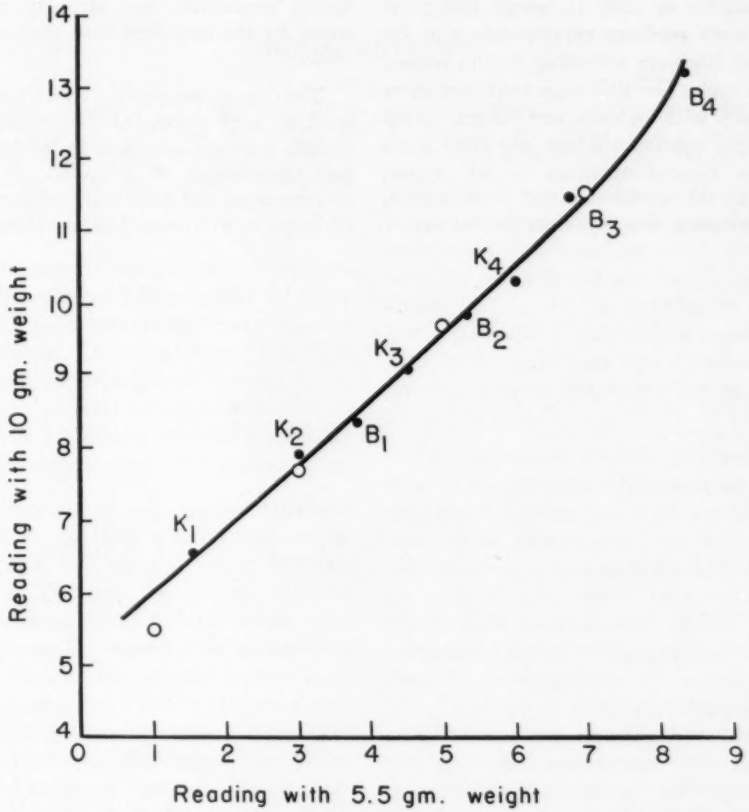
*The series of measurements designated by the letter B were made by Dr. E. J. Ballintine; those designated by the letter K were made in the Glaucoma Clinic of the Illinois Eye and Ear Infirmary.

to determine the true relationship between the 5.5 gm. and 10 gm. tonometric scale readings in the type of eye encountered in the practice of ophthalmology.

The range of normal and low ocular tensions, the Committee felt, was best represented by Ballintine's series of measurements, which had all been taken by himself with an electronic tonometer of well-known physical characteristics on office patients free of major ocular disease ("the general run of office patients"). To represent the range of high ocular tension, the Committee chose a series of measurements taken in the Glaucoma Clinic of the Illinois Eye and Ear Infirmary by one experienced examiner with one certified Schiøtz tonometer. Since there was at least a theoretic possibility of changes in ocular rigidity under the influence of persistently high or low tension, the data were divided into classes of approximately 1.5 scale unit width. The means for each group were calculated with and without the inclusion of the most extreme variants. No significant differences were found between these two sets of means. The means, therefore, may be considered as essentially uninfluenced by the presence of eyes with unusual ocular rigidity.

The Committee feels that the combined data as shown in table I and graph 1 represent the relationship between the scale readings for the 5.5 gm. and 10 gm. weights with a reasonable degree of accuracy. The curve expressing the relationship between the scale readings with the two weights is in satisfactory agreement with the 1955 scale except for the lower end, which represents the range of high ocular tensions. An attempt to eliminate this slight residual discrepancy by the method used by Friedenwald in the foregoing paper has been unsuccessful. Any further changes in the values of the constants b and B that will bring the lower ends of the two curves closer together disturbs the existing close agreement between the other portions of the two curves.

In its present form the 1955 scale is self-consistent to a greater degree than any of the scales in use since 1924. This



GRAPH 1—Paired tonometric measurements with 5.5 and 10 gm. plunger weights. The series of measurements designated by the letter B were made by Dr. E. J. Ballintine; those designated by the letter K were made in the Glaucoma Clinic of the Illinois Eye and Ear Infirmary. Empty circles mark the 1955 scale.

TABLE II

SCALE READING WITH 5.5 GM. WEIGHT	CORRESPONDING SCALE READING WITH 10 GM. WEIGHT				
	SCHIOTZ		FRIEDENWALD		EMPIRICAL
	1924	1948	1954	1955	
1	5.05	6.00	6.38	5.52	6.05
3	7.20	8.40	8.74	7.68	7.80
5	9.40	10.75	10.96	9.72	9.55
7	11.55	13.00	13.10	11.67	11.45

is shown in table II, which lists pairs of scale readings corresponding to the same pressure according to the respective scale. The 1955 scale conforms more closely with the empirical 5.5 gm. versus 10 gm. relationship than any other scale. This close conformity is, of course, partly due to the fact that Friedenwald, in selecting new constants for his curve-fitting procedure, was strongly influenced by the empirical data then available.

The Committee concurs with Friedenwald in "hoping that the 1955 scale represents a closer approach to the truth" and recommends its adoption, in full awareness of the possibility of further revisions as additional data are obtained.

BOOK REVIEWS

AN ATLAS OF DISEASES OF THE EYE. By E. S. Perkins, M.B., F.R.C.S., and Peter Hansell, M.R.C.S., F.R.P.S. Little, Brown and Company, Boston 1956. Cloth, 86 pp., 203 illustrations, mostly in color, $10.00.

This atlas is made up of reproductions of drawings and photographs by eight-color photolithography on Gateway Twinprint Cartridge paper. The light green background, with absence of reflection usually encountered in the use of highly polished calendar papers, affords fairly natural color reproductions.

The pictures are on the right-hand pages of the book with legends and descriptive text on the facing left-hand pages. The text consists of diagnosis, description, and, in some cases, comments on the character or incidence of the disease. The subject matter is divided into five parts: Lids and Orbit; Conjunctiva and Cornea; Uveal Tract and Lens and Retrolental Fibroplasia; The Fundus in Systemic Disease; and The Fundus in Local Disease. While the fundus in systemic and local disease is given a prominent play, only three pictures show slit lamp gonioscopy. Most of the pictures are of typical, commonly seen eye diseases which are readily recognized. The atlas is valuable to beginners in ophthalmology and to those who are in private practice or in small clinics where some of the conditions, such as Coats's disease, Mooren's ulcer, and retrolental fibroplasia, are seldom seen. It is decidedly a valuable handy reference atlas for office use.

W.L.B.

ENVIRONMENT AND THE DEAF CHILD. By Steven Getz. Charles C Thomas, Springfield, Illinois, 1953. 173 pp.

In a relatively small book based on a doctoral dissertation, this author has undertaken a tremendous task. As he says, the research was an attempt, principally, to classify the thinking in this field into major trends and to examine their basic similarities and differences, but then beyond that, to put the results to the test.

The criterion of value in this assessment is the personal adjustment of the deaf child. On the basis of published material on education of the deaf and discussions with leaders in the field, seven areas of achievement were selected which were considered of prime importance in the adjustment of deaf children. The variables were (1) age at entering school, (2) ability to communicate with the deaf and with those who hear, (3) vocational achievement, (4) social maturity, (5) reading achievement, (6) visual functioning, and (7) intellectual functioning. A suitable variety of standard scales and experienced judgments were employed to measure performances, and appropriate statistical criteria were applied in evaluating the results.

The 66 subjects for the study were selected from the student population at the New York School for the Deaf at White Plains, a residential school for boys only. For purposes of comparison they were divided into a group of 31 adjusted students and a group of 35 who were maladjusted.

The author interprets the results of the investigation as support of the hypothesis that maladjustment of deaf students is associated more with negative environmental experiences than with organic or hereditary conditions. He concludes that the curricula of the schools for the deaf need a revision which stresses those aspects expected to improve the interpersonal functioning of the individual.

The extent to which the ambitious goal of this research is accomplished must be judged by the reader. The present reviewer finds considerable merit in both the objectives and methods of the study. In the discussions that accompany the presentation of data the author has shown keen insight into the problems of the deaf. He has compiled and documented the expression of opinion from numerous writers in the field.

As in most research of limited depth and scope, the basis for conclusion of broad application is lacking. However, this limitation should not detract from the significant value of this contribution. Certainly it should serve as a stimulus and provide guidance for further research on the problems of adjustment in deaf children and on the effectiveness of educational facilities for the deaf. Educators and students who are concerned with the training and development of deaf children will welcome this book to their libraries.

LeR. D. H.

HAVE YOU CHANGED YOUR ADDRESS

To ensure uninterrupted delivery of your TRANSACTIONS, please return this coupon or send the same information on a post card to
American Academy of Ophthalmology and Otolaryngology
100 First Avenue Building, Rochester, Minnesota

Name .....
PEASE PRINT

FORMER ADDRESS:	NEW ADDRESS:
Street.....	Street.....
City.....	City.....
Zone.....State.....	Zone.....State.....

For countries outside the United States:

.....
NAME OF COUNTRY

News - - - Notes

AMERICAN ORTHOPTIC COUNCIL

The annual examinations of orthoptic technicians by the American Orthoptic Council will be conducted in August and October 1957.

The written examination will be non-assembled and will take place on Thursday, August 22, in certain assigned cities and will be proctored by designated ophthalmologists.

The oral and practical examinations will be on Saturday, October 12, in Chicago, just preceding the meeting of the American Academy of Ophthalmology and Otolaryngology.

Application for examination will be received by the office of the Chairman of Examination, Frank D. Costenbader, M.D., 1605 22nd St. N.W., Washington 8, D. C., and must be accompanied by the examination fee of $30. Applications will not be accepted after July 1, 1957.

The Basic Course in Orthoptics for Technicians, sponsored by the American Orthoptic Council, will be held in the Department of Ophthalmology, University Hospitals, Iowa City, Iowa, from June 19 through August 10, 1957. As usual, there will be didactic lectures and practical demonstrations, given by an outstanding faculty.

AMERICAN RHINOLOGIC SOCIETY

The American Rhinologic Society will hold its third annual meeting on Saturday, October 19, 1957, in room 14 at the Palmer House, Chicago.

NATIONAL SOCIETY FOR PREVENTION OF BLINDNESS

The National Society for the Prevention of Blindness has announced recent grants totaling $26,500 for ten eye research projects.

According to Dr. Franklin M. Foote, Executive Director, the awards are as follows:

Dr. Arnall Patz, Baltimore, $5,000, Retrolental Fibroplasia

New York Eye and Ear Infirmary, $2,000, Electrophysiology of the Eye

University of Nebraska Medical School, Omaha, $4,000, Adrenocorticoid Function in Relation to Diabetic Retinitis

Wills Eye Hospital, Philadelphia, $3,000, Choroidal Circulation

New York University-Bellevue Post Graduate Medical School, $2,000, Pancreatic Dornase in Inflammatory Ocular Exudates

Washington University School of Medicine, St. Louis, $2,500, Photocoagulation of the Retina

Albert Einstein College of Medicine, New York, $1,000, Fields of Vision Studies

Medical College of Georgia, Augusta, $2,000, Bacteriology of Uveitis

University of Chicago, Department of Pharmacology, $2,500, Synthesis of Carbon-14 and Sulphur-35 Radioactively Labelled Diamox

Beth Israel Hospital and Massachusetts Eye and Ear Infirmary, Boston, $1,500, Development of Effective Apparatus to Test Vision in Early Infancy by Means of Optico-Kinetic Response

The National Society's grant for continuing studies in retrolental fibroplasia is part of a $15,000 grant established in 1953 by the E. Matilda Ziegler Foundation.

The nation's leading nonprofit sight-conservation agency, the Prevention of Blindness Society carries on a year-round program of research, service and education. The organization is supported by voluntary contributions to its headquarters at 1790 Broadway, New York 19, N. Y.

NATIONAL COUNCIL TO COMBAT BLINDNESS, INC.

The National Council to Combat Blindness, Inc., in accordance with its program concerned with the financing of research in ophthalmology and its related sciences, announces that applications for its 1957-1958 Grants-in-Aid and Fellow-

ship Awards will be considered at the eighth annual meeting of the organization's Scientific Advisory Committee, to be held in the spring of 1957. The closing date for receipt of completed applications for Grants-in-Aid and Fellowship Awards is April 15, 1957.

Applications for Summer Student Fellowships will be reviewed in advance of the meeting, and such applications should be filed with the office of the organization no later than April 1, 1957.

All applicants for fellowships are required to make their own arrangements for suitable research facilities with accredited institutions.

Appropriate forms may be obtained by addressing: Secretary, National Council to Combat Blindness, Inc., 30 Central Park South, New York 19, N. Y.

FLORIDA

The Third Postgraduate Course in Esophageal Speech and Organic Voice Problems, sponsored by the University of Miami School of Medicine, will be held June 17-30, 1957. The course is under the direction of Nathaniel M. Levin, M.D., and other members of the faculty.

Traineeships (tuition and traveling expenses) valued at $250 are available on application. Otolaryngologists and speech pathologists are eligible to attend. Address: Dean Homer Marsh, University of Miami School of Medicine, Coral Gables, Florida.

ILLINOIS

The Central Illinois Society of Ophthalmology and Otolaryngology will meet at the Urbana Lincoln Hotel, Urbana, Illinois, on April 5, 6 and 7, 1957. Speakers will be Mr. Jack Copeland, Chicago, Illinois; Dr. Henry P. Wagener, Rochester, Minnesota; Dr. Kenneth Craft, Indianapolis, Indiana.

IOWA

The meeting of the Midwestern Section of the Association for Research in Ophthalmology will be held in the Department of Ophthalmology, College of Medicine, State University of Iowa, Iowa City, Iowa, on Saturday, March 30 and Sunday, March 31, 1957.

NEW YORK

Dr. Louis Kleinfeld has been appointed associate attending otolaryngologist at Mount Sinai Hospital, New York City.

OHIO

Ohio State University will present a Postgraduate Course in Ophthalmology March 4-5, 1957. Speakers will be Francis H. Adler, M.D., University of Pennsylvania; George J. Hamwi, M.D., Ohio State University; John W. Henderson, M.D., University of Michigan; William E. Hunt, M.D., Ohio State University; Jay Jacoby, M.D., Ohio State University; Alfred E. Maumenee, M.D., Johns Hopkins University; Ted Suie, Ph.D., Ohio State University.

The course will begin with registration at 8 a.m., Monday, March 4. Sessions will be held in the Ohio Union Building Conference Theater.

Registration fee is $20.00. Registration by mail is desirable. Address all inquiries to William H. Havener, M.D., Department of Ophthalmology, University Hospital, Columbus, Ohio.

PENNSYLVANIA

Albert P. Seltzer, M.D., has been appointed director of the Rhinoplastic and Otoplastic Clinic at the Graduate Hospital of the University of Pennsylvania.

WASHINGTON, D.C.

Ophthalmologists from across the country have been invited to attend the Third Biennial Postgraduate Course in Ophthalmology at Walter Reed Army Medical Center, Washington, D. C., March 18-20, 1957. From 3,000 to 4,000 leaders in the field are expected to participate in the program, which is being held in conjunction with the Sectional Meeting of the American College of Surgeons.

According to Col. William L. Spaulding, Chief of Walter Reed Eye Clinic, "those who had originally planned to stay for just one day, after seeing the program, have expressed the desire to spend the entire three days in study." Topics to be covered in the postgraduate course range from corneal transplantation to glaucoma to cataract surgery. Pa-

pers reflecting the latest concepts in diagnosis, treatment, and care of patients will be delivered.

Members of the Walter Reed staff who will lecture during the sessions are Col. Francis W. Pruitt, chief of the Department of Medicine; Drs. Frank B. Walsh and G. Victor Simpson, Walter Reed consultants; Lt. Col. George J. Hayes, chief of the Neurosurgery Service, and Drs. James A. Stokes and John R. Weimer, senior residents in ophthalmology. Speakers will also include Dr. Lorenz E. Zimmerman and Lt. Col. Raymond A. Skeehan, Jr., of the Ophthalmic Pathology Section of the Armed Forces Institute of Pathology.

Other doctors on the program will be Trygve Gundersen, Byron Smith, Ramon Castroviejo, Charles Iliff, Merrill J. Reeh, Marshall M. Parks, Arthur J. Jampolsky, Ludwig von Sallmann, Francis Heed Adler, Harold G. Scheie, Paul A. Chandler, Joseph S. Haas, Kenneth E. Hudson, A. Edward Maumenee, Derrick Vail, Harvey E. Thorpe, Joseph Wadsworth, Irving Leopold, John S. McGavic, Charles L. Schepens, James O'Rourke, and Benjamin Rones.

WEST VIRGINIA

The West Virginia Academy of Ophthalmology and Otolaryngology will hold its annual meeting at The Greenbrier, White Sulphur Springs, West Virginia, May 31 through June 1, 1957.

POSITIONS AVAILABLE

OPHTHALMOLOGIST wanted by large medical partnership in Southern California to complete a four-man department. Ample opportunity to do all phases of eye surgery. Opportunity for partnership; many favorable working conditions and benefits. Candidate must be Board-certified or eligible. Salary open. For detailed information write Carl Reiter, M.D., 1415 N. Vermont Avenue, Los Angeles, Calif.

OTOLARYNGOLOGIST wanted by large medical partnership in southern California to complete a four-man department. Ample opportunity to do all phases of head and neck surgery. Opportunity for partnership in third year. Many favorable working conditions and benefits. Candidate must be Board-certified or eligible. Salary open. Write to Leonard S. Buck, M.D., 130 North La Cienega Blvd., Los Angeles, Calif.

OTOLARYNGOLOGIST wanted immediately to take over going practice of thirty years, available because of necessary retirement. Town of 35,000 and growing rapidly. North Carolina license and Board certification required. Contact: M. Edward Bizzell, M.D., Box 35, Wachovia Bank Bldg., Goldsboro, N. C.

Listings of positions available should be sent to W. L. Benedict, M.D., 100 First Avenue Building, Rochester, Minn., by the fifth of the month preceding publication. They should include (1) type of physician wanted (ophthalmologist or otolaryngologist; diplomate, resident, etc.); (2) type of position to be filled; and (3) whom to write for further information. Unless otherwise requested, listings will be published once only.

1957 ANNUAL MEETING

OCTOBER 13, 14, 15, 16, 17, 18

PALMER HOUSE

Write Now

to: Palmer House for room reservations, giving date and time of expected arrival and departure; type of room desired; and number of persons to a room.

PAPERS AND SCIENTIFIC EXHIBITS SOLICITED

Write Now

to: Dr. Eugene L. Derlacki, Secretary for Otolaryngology, 55 East Washington Street, Chicago 2, Illinois.

to: Dr. Kenneth L. Roper, Secretary for Ophthalmology, Prudential Plaza, 130 East Randolph Street, Chicago 1, Illinois.

Advance Orders

for Instruction Courses for members only. Watch for the program in the MARCH-APRIL TRANSACTIONS.

THE EYE
EMBRYOLOGY SLIDES
IN COLOR

2x2" glass mounted, 200 slides	$125.00
2x2" cardboard mounted, 200 slides	75.00
35 mm film strips, 200 pictures	25.00
Motion Picture in color with sound 16 mm, 1300 feet, 40 minutes	250.00

THE EAR
EMBRYOLOGY ALBUM

200 High Fidelity Pictures in Color

Made especially for this album, unmounted, for students, teachers, anatomists, artists and otologists — only 25 sets available, for use with or without the motion picture.

EMBRYOLOGY OF THE EAR

3330 feet, in color, with sound	$500.00
With album	100.00
Total	$600.00
Album alone	$125.00

Write for partial payment plan to

DR. W. L. BENEDICT, Secretary-Treasurer
AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY
100 First Avenue Building
Rochester, Minnesota